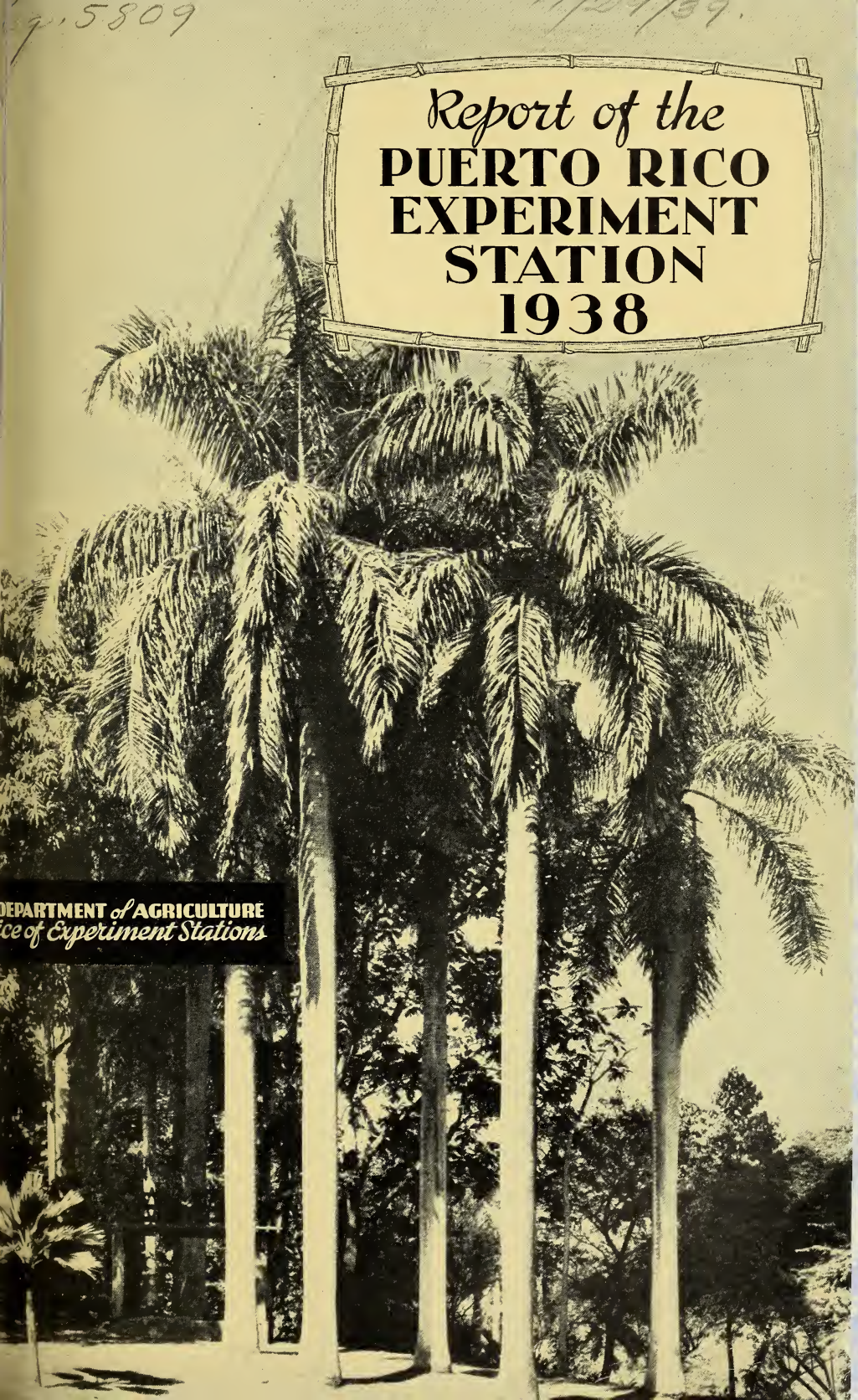
Report of the PUERTO RICO EXPERIMENT STATION 1938



DEPARTMENT of AGRICULTURE
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PUERTO RICO EXPERIMENT STATION
of the
UNITED STATES DEPARTMENT OF AGRICULTURE
MAYAGUEZ, PUERTO RICO

REPORT OF THE PUERTO RICO EXPERIMENT STATION 1938

Issued November 1939

UNITED STATES DEPARTMENT OF AGRICULTURE
OFFICE OF EXPERIMENT STATIONS

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On the front cover is reproduced a view of a clump of royal palms (*Roystonea* (*Oreodoxa*) *regia*) which have been growing at the experiment station for over 30 years. The typically tropical foliage of a breadfruit tree (*Artocarpus communis incisa*) lends a background to the symmetrical trunks of the palms.

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CONTENTS

INTRODUCTION

Scarcity of land indicates necessity for crops of high value per acre.

It is desirable for an understanding of the work reported here to review briefly some of the conclusions recorded in previous annual reports of this experiment station. It was pointed out in the report for 1937 that the census of Puerto Rico for 1935 recorded a population which, when averaged, showed 501 people per square mile and but 0.48 acre of arable land available per person. Previous annual reports have also shown that 80 percent of the exports are of direct agricultural origin, fluctuating somewhat from year to year. Puerto Rico is, therefore, largely dependent upon agriculture and the products of its soil for income. With less than one-half acre of arable land per person, and income largely dependent upon agriculture, it follows that crops to be grown in the island should be of high value per acre if reasonable standards of living are to be maintained.

Acreage of arable land has steadily decreased.

In the last annual report data were compiled from the census figures for 1910, 1920, 1930, and 1935, showing that between the years 1910 and 1935 the total area of land in farms steadily decreased from 2,085,162 acres in 1910 to 1,913,047 in 1935. The percentage

decrease in area of arable land during the same period was even greater; the census recorded 1,570,304 acres in 1910, and this diminished steadily each census year until 1935 when only 827,350 acres of arable land were recorded, a decrease of 47.3 percent in 25 years.

Thus, with a constantly increasing population, there has been at the same time a steady and serious decrease in acreage of arable land. In previous annual reports soil erosion was discussed as a probable important factor in causing this reduction. The conclusion was also developed that not only should land-utilization and crop-selection studies be used to increase the acreage of arable land, but also the periods during which land is permitted to lie idle could be studied to effect more constant utilization of arable land and increase the income per acre.

Soil conservation is an essential factor in economic reconstruction.

Previous annual reports have pointed out also the established phenomenon that the largest concentrations of plant nutrients usually occur in the surface soils. These plant nutrients are the accumulations of many years of biological activities and physical processes in the soil and in an agricultural country constitute a large part of the wealth of such a country. In soil erosion topsoils are usually lost first. Accumulated plant nutrients of centuries, if unprotected, may be washed away in the topsoils in a single afternoon of intense rain, and thus such much-needed agricultural resources are completely lost. With the intense rains and steep hillsides in many parts of the island, soil erosion has been accentuated.

It is natural that agricultural policies in crop selection should be guided by the necessity of preventing erosion and conservation of the fertile topsoils as well as by the low average area of land available per person.

Hurricane damage can be minimized by proper land utilization and crop selection.

In a previous report it was pointed out that nine serious hurricanes have struck the island during the last 111 years, an average of one every 12 years. In studies of agricultural policies the expectancy of hurricanes should be considered. Hurricane damage may be minimized by the selection of not only low-lying, hardy crops but also quick-growing annual crops in which loss of investment would be less than in orchard or tree crops, which require 4 to 8 years of continuous investment before coming into bearing. The utilization of the steep-sided valleys for tree crops has also been discussed. Bamboos that are typhoon-resistant in the East Indies are also being tried as windbreaks.

Production of winter vegetables capitalizes upon island climate.

In the last annual report, weather records were discussed and certain climatic factors were indicated as valuable assets. Puerto Rico is the only considerable land area of the United States near the more thickly populated eastern seaboard that can produce winter vegetable crops with the assurance of freedom from frost. Parts of the island also have abundant, well-distributed rainfall, such conditions constituting a considerable asset for the production of certain crops. The semiarid conditions of other parts are also an asset for other types of crops. Previous reports have called attention to ways in which careful

regional planning and study of land utilization can largely turn these climatic features, liabilities for certain classes of crops, into assets for properly selected crops.

The Puerto Rico experiment station also serves continental agriculture.

In previous reports it was mentioned that because of favorable climatic conditions at this experiment station it is possible to carry on a number of projects of service to agriculture in the continental United States.

FIGURE 1.—A view of the main office and laboratory building of the Puerto Rico Experiment Station at Mayaguez, P. R. Following a policy developed by the Department of Agriculture in Washington, the experiment station now serves as an aid to develop inter-American activities, and as a tropical outpost for the Department. Members of the field personnel of several bureaus of the Department and of other departments of the Federal Government in Puerto Rico are provided with laboratory and office space at the experiment station.

Whereas sweetpotato plants rarely flower in the north, they do flower and produce seed in this climate. Opportunity has been taken of this feature to grow some of the continental sweetpotato varieties and cross-pollinate them. The resulting seed has been sent north for germination and observation, and varieties with new combinations of characters can be logically expected. Evidence has been accumulated during the past 3 years which indicates that this experiment station could further supplement and accelerate the breeding programs of Federal and State governmental agencies on the continent by serving as a winter breeding area for certain warm-season vegetable and agronomic crops such as cucumbers, muskmelons, squash, watermelons, tomatoes, peppers, eggplant, okra, lima beans, garden beans, field beans, soybeans, and cowpeas, which can be grown in Puerto Rico during the winter months.

The most valuable rotenone-producing plants are tropical speciesl and extensive studies have been carried on with such insecticida,

plants with the object of aiding in the control of crop pests on the continent. The quinine plantings of the station are being increased each year, and more experience is accumulating as to methods of cultivation of this difficult crop. The plant-introduction garden of economic plants has been maintained and augmented with new species, some of which may ultimately enter into industry or commerce in the north.

Beneficial insects have been introduced into Puerto Rico, multiplied, and then reshipped or forwarded to the continental United States in order to control crop pests there.

These are only a few of the projects which have been carried on at the experiment station with the purpose of using the tropical climate of Puerto Rico to be of service to the people of the continental United States.

Experiment station serves as a tropical outpost for the Department.

It has been a policy of the Department of Agriculture administration to have this experiment station serve as an outpost in the Tropics at which various bureaus of this Department and other departments of the Federal Government could make their headquarters. This function of the experiment station has been gradually increasing in the past 3 years. It is also becoming apparent that the experiment station may function to aid in the development of inter-American activities of the Department.

During the year under review, the station has made field areas available for the Forest Service and Soil Conservation Service. Laboratory and office space has been made available for the activities of the Bureau of Entomology and Plant Quarantine and the Soil Conservation Service as well as the Geological Survey of the Department of the Interior. Cooperative work has been carried on for the Bureau of Plant Industry in the absence of personnel of that Bureau. Office space has also been made available for the personnel of the Plant Quarantine Service of the Insular Department of Agriculture and Commerce.

A view of the building which houses these activities is shown in figure 1.

With the foregoing review of previous work, the logic of some of the projects undertaken and summarized in the following report will be more evident.

TRENDS IN PUERTO RICAN AGRICULTURE

Number of farms has decreased.

With the appreciation of the fact that the total acreage in farms and areas of arable land have steadily decreased in the last 25 years, it has been of interest to study the nature of the farms, insofar as this has been affected by decreased farming areas.

The census figures from 1910 to 1935 have shown the number of farms and areas of land in farms of several size classifications; these data, compiled from the census figures of 1910, 1920, 1930, and 1935, are shown in table 1. The cuerda used in table 1 and in the discussions which follow is a unit of land measure used in Puerto Rico, equivalent to 0.97 acre.

TABLE 1.—*Number and area of farms in stated years* [1]

Size of farm (cuerdas [2])	Farms				All land in farms				Distribution by cuerdas			
	1910	1920	1930	1935	1910	1920	1930	1935	1910	1920	1930	1935
	Number	*Number*	*Number*	*Number*	*Cuerdas* [2]	*Cuerdas* [2]	*Cuerdas* [2]	*Cuerdas* [2]	*Percent*	*Percent*	*Percent*	*Percent*
3 or less	----------	1,127	2,128	1,782	----------	----------	3,909	3,305	----------	----------	0.2	0.2
3 to 9	----------	14,854	24,392	25,326	----------	----------	127,523	131,820	----------	----------	6.4	6.9
10 to 19	----------	9,621	11,067	11,166	----------	----------	147,503	147,770	----------	----------	7.5	7.7
19 or less	42,004	25,602	37,587	38,274	257,922	215,222	278,935	282,895	12.4	10.7	14.1	14.8
20 to 49	8,872	8,467	8,835	8,389	268,234	255,199	264,712	250,339	12.9	12.6	13.4	13.1
50 to 99	3,728	3,493	3,351	3,137	250,691	234,993	226,464	211,324	12.0	11.6	11.4	11.0
100 to 174	1,726	1,639	1,570	1,488	221,306	209,541	201,928	189,193	10.6	10.4	10.2	9.9
175 to 499	1,502	1,408	1,255	1,167	424,039	390,959	339,945	315,838	20.3	19.3	17.2	16.5
500 or more	539	469	367	335	662,970	716,490	667,490	663,458	31.8	35.4	33.7	34.7
All farms	58,371	41,078	52,965	52,790	2,085,162	2,022,404	1,979,474	1,913,047	100.0	100.0	100.0	100.0

[1] Figures are compiled from Census of Puerto Rico for the years 1910, 1920, 1930, and 1935.
[2] 1 Cuerda equals 0.97 acre.

From 1910 to 1920 large farms decreased in number but increased in acreage.

In addition to showing that the total area in farms has steadily decreased in the past 25 years, table 1 shows a decrease of almost 10 percent in the number of farms.

It is interesting to observe in the 10-year period from 1910 to 1920, that although there was a decrease in the number of farms of 500 cuerdas or more nevertheless the total area of such farms increased from 662,970 to 716,490 cuerdas. The average size of farms in this classification of 500 cuerdas or more increased from 1,230 cuerdas in 1910 to 1,528 cuerdas in 1920.

During the same period, however, farms of all other size classifications decreased in both numbers and total areas.

From 1920 to 1935 large farms decreased in number as well as total area.

During the period from 1920 to 1935, farms of 500 cuerdas or more steadily decreased in both number and total area. Nevertheless, of the 335 farms recorded by the census in 1935 in this category of 500 cuerdas or more, the average size had increased to 1,980 cuerdas.

Farms of 175 to 499 cuerdas continued to show a steady loss in both number and total area during the 15-year period from 1920 to 1935, and farms of 100 to 174 cuerdas and those of 50 to 99 cuerdas also showed steady decreases. In farms in the next to the smallest classification, namely, from 20 to 49 cuerdas, there was little more than a trend towards decrease, either in number or in total area.

Number of small farms has increased 49 percent in last 15 years.

During the 10-year period from 1910 to 1920, the smallest-sized farms, those of 19 cuerdas or less, decreased markedly, but since 1920 there has been a steady increase of these small farms. It is a commonly voiced opinion that small farms are being bought up by the large corporations; this may have been true in the period 1910 to 1920, but the figures do not confirm this in the later census years. In the 15-year period from 1920 to 1935, there was an increase of 49 percent in the number of farms of 19 cuerdas or less and an increase of 31 percent in their total area.

A logical conclusion from the foregoing figures is that consolidation of land in large farms, those of 500 cuerdas or more, has been by the acquisition of farms in the larger size classifications and not by the absorption of small farms. The decrease in area of farms in the classification of 50 to 499 cuerdas may also be logically explained by the division of inherited lands by heirs.

The data contained in table 1 are shown more clearly in figure 2.

Export figures show trends in agricultural production.

An understanding of some of the crop trends which have taken place in Puerto Rican agriculture can also be obtained by summarizing the values of agricultural exports as in table 2.

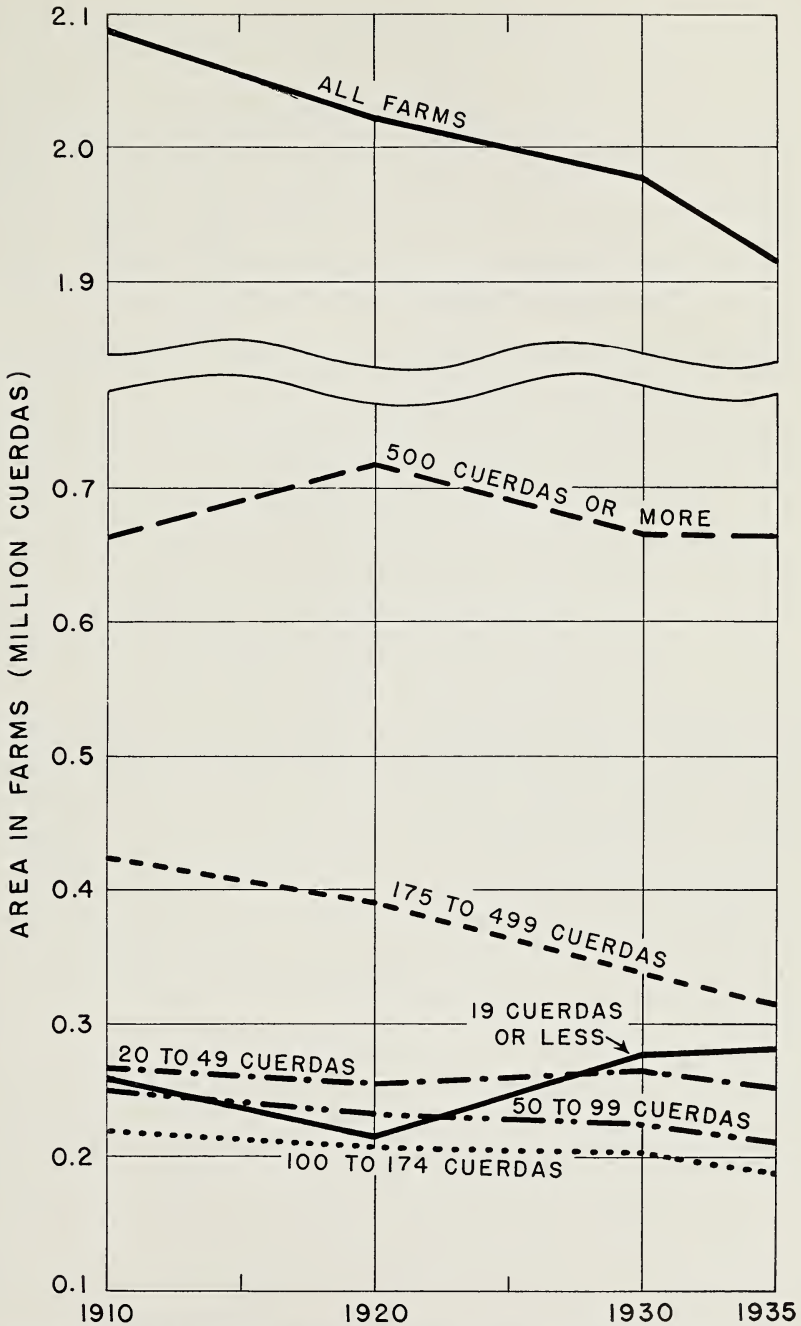

FIGURE 2.—Changes in total areas occupied by farms of different size classifications, 1910–35.

TABLE 2.—*Export value of 10 principal crops from Puerto Rico, fiscal years 1934–38*[1]

Crop	1934	1935	1936	1937	1938
Sugarcane	$55,487,376	$50,814,185	$62,351,394	$73,160,171	$51,881,263
Rum			1,040,409	2,028,231	3,106,909
Tobacco	7,864,381	8,506,567	10,371,298	10,114,983	8,483,724
Pineapples	1,056,673	911,219	1,183,424	1,213,978	939,451
Canned and prepared fruits	355,905	665,394	699,600	886,310	581,369
Coconuts	171,259	232,782	325,718	329,685	297,783
Grapefruit	1,257,632	486,765	790,069	315,580	270,225
Fruit juices	11,308	34,673	107,675	391,570	174,702
Fresh vegetables	140,207	165,635	177,132	226,316	170,171
Coffee	671,874	207,808	496,404	1,169,684	110,987
All other exports	18,957,359	18,208,174	21,590,855	25,117,319	16,060,594
Total	85,971,974	80,233,202	99,133,978	114,953,827	82,077,178

[1] Compiled from Puerto Rico Trade for the years 1934 to 1938, prepared by the National City Bank of New York. The fiscal year in Puerto Rico begins on July 1 and ends June 30 of the following year.

Since the sugar quota is more or less fixed, the values of the exports for the different years shown in table 2 reflect differences in sugar prices rather than differences in volume of shipments. The increasing value of exports of rum is a factor to be noted in increasing the income from sugarcane products even with a fixed quota for sugar in the continental United States. There is a considerable import tariff in the United States on rum from foreign countries which gives Puerto Rico a material advantage in the marketing of this product. In the case of tobacco as with sugarcane, exports during the past 5 fiscal years reflect differences in prices rather than differences in production.

Pineapples now rank third in value of agricultural exports.

It is interesting to note that next to sugarcane products and tobacco, pineapples rank third in value among agricultural exports, having replaced grapefruit in this position in recent years. The decrease in value of grapefruit exports is notable, being occasioned not only by low prices but by decreased areas harvested, a result of low prices.

There seems to be a trend towards an increase in the values of truck-crop exports, which seems logical due to the geographic position of Puerto Rico and its climatic advantages for the production of winter vegetables. The increase in value of fruit-juice exports is also notable. Values of exports of fresh vegetables and possibly certain of the other crops for 1938 were unfavorably affected by a shipping strike as well as low prices.

Coconut exports trend upward in value.

Following the extensive damage to coconut groves by the hurricanes of 1928 and 1932, there has been a gradual recovery in the exports of coconuts; most of these coconuts are shipped fresh, and further expansion would seem to be possible. There is an import tariff of one-fourth cent per nut on fresh coconuts from foreign countries, except Cuba, which gives Puerto Rico a small advantage in marketing this crop in the continental United States.

There has been a notable decrease in the value of coffee exported. The big increase in value in 1937 was due to the purchase and exportation of surplus coffee by the Puerto Rican Coffee Corporation, operating with the aid of a benefit payment of the United States Department of Agriculture made available under section 32 of the authorizing act of the Agricultural Adjustment Administration, on coffee shipped to the continental United States.

Sugarcane yields good income per acre.

Additional trends in Puerto Rican agriculture may be observed in a comparison of the areas planted to important crops, as shown in the census for 1935, and the export values of these crops during that year. In table 3 are listed the number of farms in different crop categories, the total areas in such farms, the areas of the crops harvested in 1935, and the values of exports of such crops.

TABLE 3.—*Areas planted to important crops and their export values in 1935*

Crop	Farms [1]	Total area in farms [1]	Area in principal crop harvested [1]	Value of 1935 exports		Export income per cuerda harvested
	Number	*Cuerdas*	*Cuerdas*	*Dollars* [2]	*Percent*	*Dollars*
Sugarcane	6,620	758,834	245,154	[3] 50,814,185	63.3	297.27
Tobacco	13,016	252,225	45,720	[4] 8,506,567	10.6	186.05
Pineapples	847	(5)	(5)	911,219	1.1	
Canned and prepared fruits	(5)	(5)	(5)	665,394	.8	
Grapefruit	1,249	(5)	(5)	486,765	.6	
Coconuts	8,824	(5)	(5)	232.782	.3	
Coffee	9,644	401,342	182,316	207,808	.3	1.13
Unitemized	12,590	500,646		18,408,482	23.0	
Total	52,790	1,913,047		80,233,202	100.0	

[1] From Census of Puerto Rico, 1935.
[2] From Puerto Rico Trade for the year ended June 30, 1935, prepared by the National City Bank of New York.
[3] Includes raw and refined sugar, molasses, and alcohol.
[4] Includes leaf tobacco, tobacco stems and scraps, cigars, cigarettes, and other tobacco manufactures.
[5] Data not shown in census schedules.

In addition to classifications for tobacco farms and coffee farms the census included a classification "coffee-tobacco farms." The areas of coffee-farming and tobacco-farming lands therefore cannot be stated definitely. However, from the paragraphs on definitions, in the census, apparently the figures for cuerdas of tobacco harvested represent all tobacco in 1935 whether under the heading "tobacco farms" or "coffee-tobacco farms."

Sugarcane produced 63 percent of island income on 39.6 percent of farming land.

Because of the fact that the areas recorded in the census of 1935 may not have been cropped in the fiscal year 1935, some slight discrepancies may exist, but these are not of great importance inasmuch as the figures are presented chiefly for their comparative value.

The total area of 758,834 cuerdas in sugarcane farms, shown by the census, is 39.6 percent of the total area of land in farms. Of the land in such sugarcane farms in 1935, 245,154 cuerdas were harvested which produced 63.3 percent of the income of the island; the average income per cuerda from exports of sugar and byproducts amounted to $207.27. The average total income per cuerda would of course be somewhat larger because of the added value of sugar and other sugarcane products consumed in the island.

In this discussion the phrase "income to the island" is used in the sense of income exclusively from exports. Income derived from local sales of products for the purpose of discussion here, is not considered as income to the island; the phrase, "average total income per cuerda," is used several times to indicate income from exports plus income from local consumption averaged per cuerda.

Tobacco yielded 10.6 percent of island income.

Tobacco produced 10.6 percent of the island income from a harvested area of 45,720 cuerdas and yielded an average income per cuerda from exports of $186. The average total income per cuerda from tobacco would be somewhat larger due to the amount consumed locally.

Tobacco is largely produced upon steep, sloping lands. Since it is a crop that requires considerable cultivation in which the soil is disturbed frequently, from the standpoint of soil conservation it is a poor crop for hillsides. Apparently in island economy, tobacco could well be grown upon some of the level or slightly sloping sugarcane lands which are not in production because of restricted plantings as a result of the sugar quota. For individual planters with no level lands available, diversion of run-off water by contour canals, planting in contoured rows, and cropping with a vegetative cover immediately after the final harvest of the tobacco, are logical procedures to minimize erosion.

Coffee produced less than 0.3 percent of island income.

The total area in coffee farms, according to the 1935 census, was 401,342 cuerdas, amounting to 20.9 percent of the total area of all farms. In 1935, at least 182,316 cuerdas of coffee were harvested. The value of coffee exports was $207,808, less than 0.3 percent of the total income of the island. The average income per cuerda from exports of coffee was $1.13, which would be increased somewhat by the value of the coffee consumed in the island. The figures in table 3 support and emphasize the logic and policy of this experiment station in its program of searching for new and more remunerative crops for the coffee districts.

Nevertheless, until new crops with greater chances of profit are available for considerable areas, coffee groves are serving a purpose; at the experiment station, coffee, with proper cultivation practices, augmented by the overhead shade trees, the undergrowth of ferns, or grasses, and the mulch of fallen leaves, has effectively minimized soil erosion on steep hillsides.

ENGINEERING PRACTICES AND CROP SELECTION IN RELATION TO SOIL CONSERVATION

Experimental bench terraces were completed on Las Mesas.

The bench terraces begun in October 1937 in the Benet field on the Las Mesas property of the experiment station were completed during January. These terraces are all relatively short, the maximum length being 175 feet, and were laid out on a uniform grade of 0.32 foot per 100 feet. Vertical intervals that range from 2.5 to 3.5 feet among the different terraces were chosen in order to provide benches sufficiently wide to accommodate row crops requiring cultivation.

To avoid complicated lay-out, an equal pitch of 6 inches was used on all the terraces, and the outer rim of each terrace was built up from 3 to 5 inches above the desired final height to allow for settling. This method of construction gave a water channel of fairly uniform capacity throughout the entire length of each terrace.

The bank slope was built uniformly 3 feet horizontal to 4 feet vertical. Although this is a rather steep slope, it has been found to be satisfactory elsewhere on Las Mesas and at Las Ochenta when the bank was planted to erosion-resistant grasses and other plants.

These terraces cost $743 per acre.

A great deal of this terracing was done during the dry season when the ground was dry and hard. The field in which the operations were carried on was in an advanced stage of erosion, badly gullied, and had an uneven terrain that was difficult to work. The laborers employed were provided by Camp El Caribe of the Puerto Rico Reconstruction Administration and were paid $1 per day of 8 hours. One camp man, a subleader, was paid $1.40 per day. The major part of the supervision was done by a station employee who was paid at a rate of $42.50 per month. A team of oxen with driver at $1.20 per day was used as much as feasible. Other than hand tools, a plow and a home-made V-drag were the only pieces of equipment used. In all 0.74 acre of land was terraced.

Exclusive of the cost of general supervision, the cost of terrace construction and planting the banks to erosion-resistant plants was as follows:

421 man-days at $1.00	$421.00
32 man-days at $1.40	44.80
32 man-days at $1.80	57.60
22 team-days at $1.20	26.40
Total	549.80

Since only 0.74 acre was terraced, the cost was $742.97 per acre.

Narrow bench terraces cost from $385 to $502 per acre, depending on shape.

In addition to the wide bench terraces mentioned above, two types of narrow bench terraces and some modified Mangum terraces were constructed in the Benet field. A small section of the field was left untouched to show the condition of the land before terracing operations were begun.

The bank in one of the types of narrow bench terraces was rounded and the finished terrace had the appearance of a large ridge rather than a pronounced shelf; they were from 5 to 7 feet wide. Experience to date has shown that these terraces are effective erosion-control devices and are adapted to such crops as vanilla and papaya, which yield high values per acre, and the returns from which would justify considerable construction costs. In planning such a terrace system for specialized crops their spacing determines the terrace width. The construction costs, which follow, totaled approximately one-half the cost of the wide bench terraces:

616 man-days at $1.00	$616.00
41 man-days at $1.40	57.40
41 man-days at $2.00	82.00
Total	755.40

An area of 1.96 acres was terraced at a cost of $385.41 per acre.

In the other type of narrow bench terrace that was constructed, the bench was about the same width as in the type described above, but the terrace conformed to the conventional bench shape and required more care and labor to construct. The cost of construction on the 0.17 acre of land terraced amounted to $85.30, a cost of $501.76 per acre.

Construction of modified Mangum terraces cost $95 per acre.

Mangum terraces were constructed on those sections of the Benet field having a slope of less than 18 percent. These terraces were modi-

fied to render them suitable for these steep slopes which left the lower sides of the ridges too steep for tillage or planting to other than erosion-resistant plants. The cost of these terraces, built under conditions similar to those set forth above, was as follows:

113 man-days at $1.00	$113.00
6 man-days at $1.40	8.40
6 man-days at $1.80	10.80
8 team-days at $1.20	9.60
Total	141.80

An area of 1.48 acres of modified Mangum terraces was constructed at a cost of $95.81 per acre.

The experiment station has discontinued construction of bench terraces as a farm practice.

The hardness of the ground, the unevenness of the terrain, the small extent of operations, and the untrained labor without suitable equipment all helped to increase the cost of this project beyond what it would have been if trained labor and suitable machinery had been available. The foregoing figures therefore are too high to be taken as a typical cost. A tractor and trail builder in the hands of a skilled operator should substantially reduce these costs. Bench terraces when given a reasonable amount of maintenance are of a permanent nature, and the cost of construction should be distributed over a considerable period of time.

However, the foregoing records do indicate forcibly that bench terracing is a costly method of erosion control and that exceedingly shrewd land-utilization practices must be followed on the terraced land in order to make sufficient profit to justify the costs of terrace construction. Because of this high cost the experiment station has discontinued the construction of wide bench terraces as a farm practice. At present, irrigated land can be bought for $500 per acre, and unirrigated land for $300 per acre or less. Costs for terrace construction must be brought well below the original purchase cost of level or slightly sloping land before such construction seems economically feasible.

Formulas were developed for calculating earth moved in building bench terraces.

The cost of building bench terraces by hand in the Benet field prompted a study of factors affecting terrace-construction costs. Several factors were found to have a pronounced effect upon the yardage of earth moved, and two formulas were developed for calculating this yardage. A brief discussion of several of the factors is given below, together with the formulas and their application.

Figure 3 shows the cross section of a bench terrace with the original land slope indicated. Labeled, shaded triangles show the cut and fill. Other parts of the terrace are indicated by letters. I represents the vertical interval, B the width of the bench, and P the pitch or slope of the bench toward the cut. The earth from the cut makes the fill, hence cut$-$fill$=\frac{1}{8}\ B\ (I+P)$ square feet, area of section;[1] which in turn equals the number of cubic feet of earth moved per linear foot of terrace.

[1] These formulas are based on values of B, P, and I, in feet.

Mathematically the volume, V, of earth in cubic yards moved in terracing may be expressed in formulas, as follows:

Formula 1.—$V=0.463\ B(I+P)$ cubic yards per 100 linear feet of terrace.[1]

Formula 2.—$V_a=201.67\ (I+P)$ cubic yards per acre of bench surface.[1]

Formula 1 shows the volume of earth moved in relation to bench width, height, and pitch, while formula 2 is in terms of height and pitch. For convenience of calculation, it is suggested that 0.46 and 202 be used as constants in formulas 1 and 2, respectively. These values give results consistent with the accuracy expected.

It was found that practically all irregularities of the ground caused by erosion tend to increase the amount of earth that must be moved;

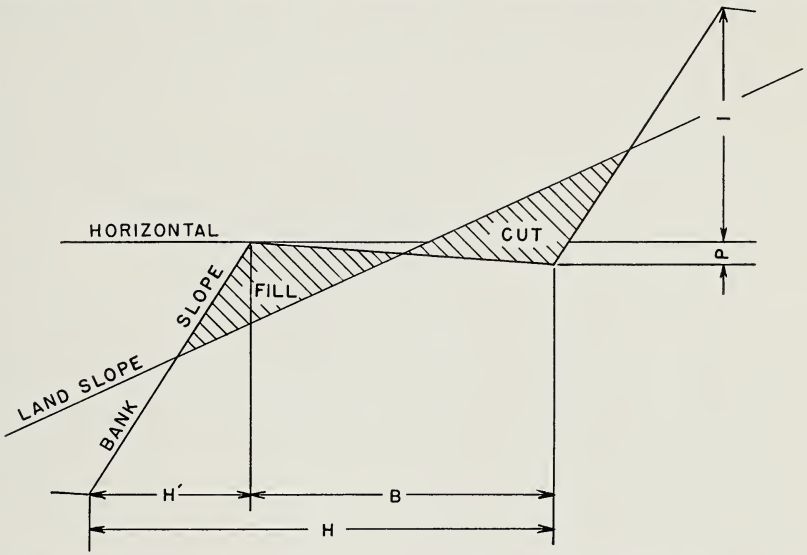

FIGURE 3.—Diagrammatic cross section of a bench terrace with original land slope indicated, showing cut and fill and component parts of the terrace: I, Vertical interval; P, pitch; B, bench width; H, width of terrace; H', horizontal component of bank slope.

hence, the results given by the above formulas represent the minimum yardage; it is doubtful that an applicable correction factor for unevenness of terrain can be determined.

Terrace costs increased with greater bench width and height.

From figure 3 it can be readily seen that bench width and height are dependent on each other. On any given land slope the bench width increases as the height is increased. Since this is true, any discussion of the effect of one of these factors must include the other.

For illustration, in a bench terrace built level, $P=0$; the earth moved per 100 linear feet of terrace is: $V=0.46\ B\times I$.

Again, since I and B are functions of land slope, in a terrace with a vertical bank $I=B\times$percent land slope. Then the volume of earth moved, V, is equal to $0.46\ B^2\times$percent land slope. In the same manner, the volume of earth may be expressed in terms of I^2 and a con-

[1] These formulas are based on values of B, P, and I, in feet.

stant; hence, the earth moved per linear unit of terrace varies with the square of the bench width or height.

In terrace construction it is impractical to use a vertical bank. Therefore, land slope cannot be expressed as $\frac{I}{B}$, and the formula $V=0.46\ B^2\times$percent land slope holds true only when a correction is made for bank slope. However, the above does illustrate the effect increased bench width and height have on the volume of earth moved per linear unit of terrace.

Again, in formula 2, which gives volume of earth moved per acre of bench surface rather than per unit of terrace length, the volume of earth moved increases directly as the terrace height is increased. On any given slope increased height increases width; hence the earth to be moved per acre increases almost directly as the bench width is increased.

Terrace costs increased with greater pitch.

A level bench is more economical to build than one sloping toward the inside, that is, toward the cut. A terrace sloping outward can be built still more cheaply, but to secure effective water control the terrace must be built to slope inward. The outer rim, or fill, must be built up so that the water will drain to the inside and along the channel, and eventually out of the field. In this discussion the difference in elevation between the rim and cut is termed pitch. Both of the formulas giving volume of earth moved include this factor. The earth to be moved increases directly as the pitch is increased. For example, a pitch of 0.5 foot requires the moving of 101 cubic yards more earth per acre of completed bench than will a level terrace.

For economy of construction as small a pitch should be chosen as will provide a water channel of sufficient capacity to adequately take care of the run-off water. A shallow canal at the back of a broad bench terrace lessens the amount of pitch needed.

Terrace costs increased with increased bank slopes.

Referring again to figure 3, it can be seen that bench width, B, is less than the horizontal width, H, by the distance H', the horizontal component of the bank slope. When the bank is vertical, $H'=0$ and $B=H$. Bank slope, which can be designated as S, is the ratio of the horizontal distance covered by the bank, represented by H', to its total vertical height. Then distance $H'=S(I+P)$. Also the area of completed bench surface is a fraction of the original land area and may be expressed as $\frac{B.}{H}$

Formula 2 gives yardage of earth moved on the basis of completed bench surface. In the calculation of the earth moved per acre of land area, the formula becomes $V=202\ (I+P)\times\frac{B}{H}$. As the bank slope approaches the vertical the fraction $\frac{B}{H}$ increases, approaching

unity as a limit, which in turn increases the value of V. While the bank slope does not affect the volume of earth moved per acre of bench surface, steep banks do increase the yardage of earth to be moved per acre of land area, and also a steep bank requires careful placing of the earth, thereby considerably increasing the labor necessary. Hence, the cost of terracing an acre of land increases as the bank slope is increased.

Bench area and yardage moved may be calculated from these formulas.

To illustrate the use of the formulas discussed above a typical problem is here assumed and worked out.

A landowner has a 2-acre field with an average land slope of 40 percent. He wants benches 8 feet wide. What will be the completed bench area, and how much earth must be moved in terracing this field?

The soil type and general field conditions indicate that a ¾-bank slope, that is, horizontal 3 feet to vertical 4 feet, and a 0.5-foot pitch will be satisfactory.

From figure 3, $\frac{I}{H}$=land slope=40 percent in this problem.

By trial, when I=4.75 feet, H=11.9 feet

$$H'=S(I+P)=\tfrac{3}{4}\ (4.75+0.5)=3.9 \text{ feet.}$$

$$B=H-H'=11.9-3.9=8 \text{ feet, bench width}$$

$$\frac{B}{H}=\frac{8}{11.9}=67 \text{ percent of land area in bench;}$$

67 percent × 2 acres=1.34 acres completed bench area.

The volume of earth that must be moved is calculated as follows:

V=202 (I+P) cubic yards of earth moved per acre of bench.

V=202 (4.75+0.5)×1.34=1,421 cubic yards of earth to be moved.

This value represents the minimum earth removal.

In the foregoing example the values for bench width, vertical interval, and bank slope were chosen for illustrative purposes only. They should not be taken as a recommendation or even a suggestion as to the most desirable bench width, vertical interval, or bank slope to use in bench-terrace construction. Such factors are necessarily flexible and will vary with the ultimate land use, soil type, terrain, and climate.

Construction of Mangum terraces has been continued.

As outlined in recent annual reports, Mangum terraces, with slight modifications depending on soil types and slopes, have been constructed on slopes up to 16 or 18 percent at costs much lower than for bench terraces. Eighteen-percent slopes on most soil types have been, in most cases, too steep for Mangum terraces. Terraces of this kind are not nearly so spectacular in appearance as bench terraces, but they have been an effective means of combating erosion on the lesser slopes at the experiment station.

Construction of contour canals is an economical practice to minimize erosion.

For steep hillsides of 18 percent or more at this experiment station, the construction of contour run-off canals has seemed to be one of the cheapest engineering devices to lessen soil erosion. The essential

function of contour canals is to lessen local volume and velocity of run-off water. Small canals, grading slightly from the contour, were placed at intervals along the slope to collect surface water and lead it out of the field at reduced velocity. The cost of construction varies with the stage of erosion, terrain, and type of soil. For tree, bush, and forage crops that require little cultivation, contour canals are effective erosion-control devices, and require only a small amount of maintenance once they have been established and grassed-in.

Vegetative covers have been effective and economical for soil-erosion control.

Soil-erosion-control practices at this station have gone through a period of evolution as have soil-conservation practices elsewhere. Efforts at first gave emphasis to engineering devices to check local

FIGURE 4.—Soil cover of dwarf bucare (*Erythrina berteroana*), jackbeans (*Canavalia ensiformis*), and cohitre (*Commelina elegans*) 8 months after planting on earth fill resulting from road construction at the experiment station. Such vegetation surprisingly lessens run-off water and holds the soil, both factors minimizing erosion.

volume and velocity of run-off water. Some of these were shown to be uneconomical, but at the same time experience was developing to show that vegetative coverings were effective in preventing erosion. Certain crop plants are particularly effective in lessening the volume and velocity of run-off water; their foliage breaks the force of the rain and their roots bind the soil. There has gradually developed, therefore, a trend towards combining the use of vegetative covers with the more economical engineering devices such as contour canals and Mangum terraces.

In the construction of artificial or engineering devices where earth is moved or loosened, as for example a contour canal, efforts have been made to secure a vegetative cover on the fresh earth as quickly as possible. It has been evident that the use of plant nutrients

plays an important part in restoring plant covers to bare earth in cuts and fills, particularly where the subsoil has been exposed. The use of chemical fertilizers to promote plant growth has thus seemed to be an important erosion-prevention practice.

Soil covers as developed in fresh cuts and fills in road construction are shown in figure 4.

Crop selection is an important erosion-control measure.

There are many crops in the Tropics for which little or no cultivation practices are necessary. A number of the grass crops can be ratooned, and, other than an occasional weeding, the soil need not be disturbed for several years. Such grasses include forage crops and several of the essential-oil plants; even sugarcane, if managed with discretion, can be utilized to check soil erosion. The foliage and root systems of grasses lend themselves particularly well to breaking the force of rain and holding the soil in place. Some essential-oil plants are bush crops, which also require little disturbance of the soil once they are planted.

Crops which require frequent cultivation, such as corn, tobacco, and cotton, have been destructive in promoting erosion when planted on hillsides. Each time that the soil has been loosened by cultivation it has been made more susceptible to being washed away by rains and run-off water. Root and tuber crops, such as sweetpotatoes, yams, carrots, and turnips, which require considerable disturbance of the soil when they are harvested, have also left the land susceptible to erosion. Quick-growing crops that mature in a few months and which require the soil to be replowed before another planting have not been suited for hillside cultivation. Where it is necessary to grow crops such as the foregoing on slightly sloping land up to 16 or 18 percent, construction of Mangum terraces has been desirable. At slopes of greater than 18 percent bench terraces would prevent erosion, but the return for most of such crops as have been mentioned would not be great enough to justify the cost of bench-terrace construction.

Many tree crops can be grown on hillsides with little erosion loss.

In general practice most tree crops in the Tropics are given little cultivation, and the soil covering is seldom disturbed or loosened after planting. The tree crops themselves, by means of their foliage and root systems, contribute considerably to lessening the loss of soil by erosion.

In general, tree crops have been selected for cropping the steeper slopes at the experiment station, those of 18 percent or more. This has evidently been good land utilization and has saved the limited areas of level or slightly sloping land for root or other crops requiring frequent cultivation. Steep slopes rising from sheltered valleys also offer the advantage of some degree of hurricane protection to tree crops.

New dam embodies automatic device for flood control.

During the year a new earth dam was constructed to serve for the storage of irrigation water, to minimize the possibilities of floods, and ultimately to serve for fish production. In this newest dam a device has been introduced to maintain automatically a level at which a reserve capacity exists in the reservoir in order to temporarily im-

pound excess water following unusually heavy rains. This has been obtained by the incorporation of an additional outlet to the spillway in the dam. In this case a 3-inch iron pipe was placed 6 feet below the uppermost spillway outlet of the dam. This additional 6 feet gives a reserve capacity for floodwater of about 20,000 cubic feet, which is approximately two-thirds of the total capacity of the reservoir. The 3-inch pipe is calculated to require from 18 to 20 hours to remove the floodwater from full capacity of the dam to the level of the flood-control outlet.

This pipe for water-level control was sloped upward from the reservoir to the spillway to minimize the possibility of stoppage from debris on the surface of the water and can be closed near the end of the rainy season to allow the reservoir to fill for irrigation purposes.

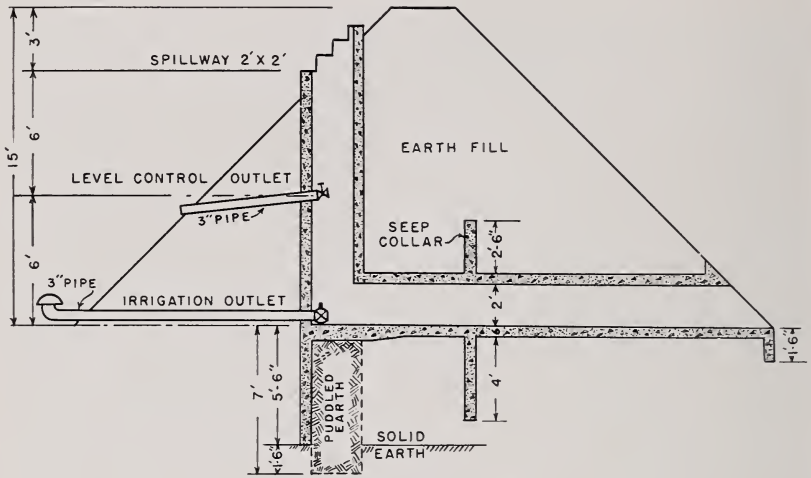

FIGURE 5.—Cross section through earth dam showing arrangement of an outlet in the spillway to provide irrigation water, a second outlet to control the water level automatically in order to keep a reserve capacity throughout the rainy season, and the uppermost outlet to carry off overflow water.

In addition to the flood-control outlet there are two other outlets in the spillway, the overflow to function when the reservoir is full, and a valve near the floor of the reservoir being the outlet for irrigation water.

A cross section of the dam showing the three spillway outlets of different functions is shown in figure 5.

Engineering practices in relation to soil conservation in the maintenance of the experiment station have been designed and supervised by James K. Alvis, assistant agricultural engineer, with the close cooperation of the personnel of the Soil Conservation Service in Washington and in Puerto Rico.

VANILLA PROCESSING AND CHEMISTRY

Bureau of Chemistry and Soils cooperated in vanilla-processing studies.

Investigations of the chemistry of vanilla processing during the year were concerned mostly with methods of extraction and analysis.

During the winter months E. K. Nelson, senior chemist of the Food Research Division, Bureau of Chemistry and Soils, cooperated at the station in the study of the action of enzymes in the curing of vanilla beans. The activities reported in the following paragraphs are the results of the work of Francisca Arana, assistant chemist, and Mr. Nelson. Appreciation is expressed to Charles F. Pennington, vanilla specialist of the station, for cooperation and helpful suggestions.

To ascertain the effect of curing methods on quality, 17 lots of vanilla beans were analyzed. All these beans were grown in Puerto Rico and had been subjected to various curing treatments at the station during the late winter and spring of 1937. For the purpose of comparing analyses, an extract of standard strength was prepared from each lot by using 10 grams of beans per 100 milliliters of 50-percent alcoholic menstruum.

Extraction methods were standardized for experiment.

The moisture content of the beans was first determined by drying samples of each lot to constant weights at 68° to 70° C. in a vacuum oven. The menstruum for the extracts was corrected to a 50-percent-alcohol basis by the addition of 95-percent alcohol according to the moisture thus found in the beans. The beans were cut into pieces approximately one-eighth inch long, and were macerated in half of the menstruum for 8 days, with a 3-hour daily period of violent agitation in a mechanical agitator for a total of 24 hours. The liquid was drained, and the extracted residuum of beans was firmly packed in glass cylinders 1 inch in diameter. The menstruum was then poured into these cylinders and allowed to percolate through the packed residuum. Then all of the reserved menstruum and additional 50-percent alcohol were added in fractions until the required volume was obtained. The vanillin content and Wichmann lead number were determined from these extracts, using the methods of analysis of the Association of Official Agricultural Chemists. The lead number is a measure of the organic matter in the alcoholic extract from the beans.

Not all of the vanillin in vanilla beans is obtained by the usual method of alcoholic extraction; therefore in order to determine the total vanillin in the beans, the final macerated residues remaining after the complete preparation of the extracts were re-extracted with ether in Soxhlet extractors. The ether extracts were evaporated and the residues dissolved in measured volumes of alcohol. Aliquot portions of this alcoholic ether extract were added to corresponding aliquots of the original alcoholic extract so that the vanillin determinations of the resulting mixture would indicate the total vanillin content of the beans.

Ethylene-gas treatment accelerated processing.

Since the beans did not have a uniform moisture content, the percent of vanillin was calculated on a dry, as well as on a moist basis in order to provide a common basis on which to compare one lot of beans with another.

Table 4 shows the type of beans analyzed, the respective curing treatments to which the beans had been subjected, the moisture and vanillin contents of the beans, and the lead number of the extracts.

TABLE 4.—*Analyses of Puerto Rican vanilla beans subjected to various curing treatments*

Lot	Type of beans	Curing treatment	Moisture content	Vanillin content [1]		Wichmann lead number of extract [1]
				Moist basis	Dry basis	
		HOT-WATER TREATMENTS				
			Percent	*Percent*	*Percent*	
A	Seconds	Dipped 3 times for 10 seconds each at 80° C., sweating at room temperature.	27.99	2.66	3.69	0.616
B	Splits	Dipped 3 times for 10 seconds each at 80° C., sweating at 55°.	24.87	2.78	3.70	.786
C	Seconds	Dipped for 20 seconds at 80° C., sweating at 55°	24.95	2.77	3.69	.680
D	Splits	Dipped for 3 minutes at 65° C., sweating at 55°	23.68	2.61	3.67	.659
		TREATMENTS WITH GASES				
H	Splits	Ethylene, 1–1,000 [2]	31.37	2.48	3.61	.719
I	do	Ethylene, 1–10,000 [2]	30.94	2.60	3.77	.713
J	do	Ethylene, 1–100,000 [2]	32.27	2.74	4.05	.635
K	do	Ethylene, 1–1,000,000 [2]	29.73	2.38	3.39	.660
L	do	Ether, 1–10,000 [2]	29.23	2.44	3.45	.705
M	do	Chloroform, 1–10,000 [2]	30.41	2.34	3.36	.639
N	do	Acetone, 1–10,000 [2]	29.54	2.60	3.69	.606
O	do	Oxygen [2]	30.22	2.51	3.60	.657
		SUN-KILLED WITH DIFFERENT METHODS OF SWEATING				
F	Splits	Sun-killed and sun-sweated	26.31	2.74	3.72	.658
P	do	Sun-killed, continuous sweating at 45° C.[3]	21.96	2.86	3.67	.659
Q	Seconds	Sun-killed, continuous sweating at 55° C.[3]	21.31	2.90	3.69	.876
R	Splits	Sun-killed, continuous sweating at 65° C.[3]	19.63	3.03	3.77	.757
		DRY-HEAT TREATMENT				
G	Splits	Oven heat [4]	25.47	3.01	4.04	.699

[1] The methods of analysis used were those of the Association of Official Agricultural Chemists.
[2] Sweated continuously at 55° C. in electric ovens.
[3] In electric ovens.
[4] Killed at 55° C., then exposed to sun, and finally sweated at 55°.

Although not shown in the table, it is of interest to note that lots H, I, J, and K, treated with ethylene and sweated continuously in an electric oven at 55° C., cured much more rapidly than any of the other treatments. This would be of some advantage, not only in saving in labor costs, but also in interest charges on a high-value product and the ability to market earlier.

The heavy formation of vanillin crystals on the ethylene-treated beans within a few weeks after completion of processing was a feature of this treatment. Although such crystals gradually disappeared during storage, this was shown to be due largely to sublimation of the crystals.

It is unfortunate that two classes of beans were used throughout the experiment. However, the results are included as at least presenting a number of ideas if not conclusions.

Sun-killed beans showed greatest losses in weight.

It can be seen from table 4 that treatments of lots F, P, Q, and R, in which the beans were exposed to the sun for killing, resulted in much the greatest loss in weight, the moisture content of the cured beans

varying between 19.63 and 26.31 percent. This contrasts with the moisture content of the beans which were killed by exposure to ethylene, in which the moisture content varied between 29.73 and 32.27 percent.

There was a difference of 10 percent in the weight of cured beans in favor of the ethylene treatment, which would be advantageous for enzyme activity. The moister beans were also more flexible and had a more attractive color and appearance. Although the dry beans would be expected to be less subject to damage from molds, apparently other procedures will enable the beans to escape mold damage even with the higher moisture content.

Sweating at lower temperatures lessened moisture loss.

In lots P, Q, and R there was a definite correlation between the sweating temperatures and the final percentages of moisture of the cured beans. At a temperature of 45° C. the moisture content was somewhat greater than at higher temperatures, and the curve of moisture loss was constant and inversely related to the increased temperatures.

In lots A, B, C, and D all beans were exposed to hot water, but for different intervals of time, or different temperatures of water or subsequent sweating; despite the two types of beans under test, there were no great differences in moisture content and even less significant differences in vanillin content. Apparently small differences in lengths of exposure to hot water or in number of submersions in hot water have but slight effect on the moisture and vanillin contents of the cured beans and their bouquet.

Vanillin content on a moist basis has little significance in comparing the different treatments. To the buyer, of course, moisture figures should be important, inasmuch as the higher the moisture content the less value he is receiving in the form of vanillin and other factors yielding bouquet. However, if fine bouquet results from small concentrations of esters and volatile oils, as sometimes suspected, as well as from vanillin and resins, the beans that are excessively dried would be expected to have less value because of the greater loss of such flavoring compounds from volatilization, sublimation, and oxidation.

Vanillin content on dry basis was relatively uniform for all treatments.

On the dry basis uniformity of the vanillin content from almost all treatments was notable. Twelve of the seventeen treatments showed vanillin contents which ranged between 3.60 and 3.77 percent.

The average vanillin content of the ethylene-treated beans was almost identical with that of the sun-killed beans. The average vanillin content of the beans killed in hot water was less than that of either the ethylene-treated or sun-treated beans, but probably not significantly so. The beans treated with ether and chloroform had low vanillin contents, and these treatments will be discontinued in future experiments.

In the series of ethylene-treated beans there was a consistently increasing vanillin content as the concentration of ethylene was reduced from 1 part per 1,000 to 1 part per 100,000, but when the ethylene was diluted to 1 part per 1,000,000 there was a notable drop in the vanillin content. While it is doubtful whether these differences are statistically significant, they provide a lead for future experiments.

It is difficult to draw any conclusions from the determinations of the lead numbers in the foregoing experiment, inasmuch as there seem to be no significant correlations with methods of treatment. Some investigators have questioned the value of the lead number in determining the value of a vanilla extract.

Experiment tested five methods of extraction for vanilla beans.

Five different methods of extraction were tried on identical samples of Puerto Rican vanilla beans (*Vanilla fragrans*) to determine the effect of these methods on the vanillin and resin contents and the lead number of the resulting extracts. The beans, which were second grade and of the 1936 crop, were cut to such a degree of fineness that all pieces would pass through a 10-mesh sieve. The whole lot was then completely homogenized, and the moisture content was determined by drying samples to constant weight at 68° to 70° C. in a vacuum oven.

In four methods of extraction variations in treatment consisted in using different concentrations of alcohol as solvents, the beans being macerated in the solvents for 30 days. Forty-percent alcohol was used without correction for the moisture content of the beans in lot A and corrected in volume for this moisture content in lot B. Fifty-percent alcohol was used uncorrected for lot C, and corrected for lot D. In each of these four treatments maceration was started with only two-thirds of the solvent, holding one-third in reserve in each case. After the 30-day maceration period the solvent was drained off, the fine portions of the partly exhausted beans were packed in glass cylinders, and the menstruum was poured back and allowed to percolate over them. Then the reserve solvent for each treatment was added in fractions until the beans were supposedly exhausted, more solvent being added until the volume required for standard-strength extracts was obtained.

The fifth extract, lot E, was prepared by the National Formulary method. The beans were macerated for 12 hours in a volume of water representing one-fifth of the total volume of finished extract; at the end of the 12-hour water-maceration period 95-percent alcohol, representing another fifth of the total volume of finished extract, was added, and the mixture was also allowed to macerate for 3 days. Then the liquid was drained and 47.5-percent alcohol was allowed to percolate through the firmly packed beans until the volume required for standard-strength extract was completed.

The total vanillin content of the beans was determined by re-extracting with ether the final maceration residues in the manner already described.

The vanillin and resin contents and the Wichmann lead number were then determined for all five extracts, using the methods of analysis of the Association of Official Agricultural Chemists.

Table 5 shows the respective methods used in the preparation of the extracts, the moisture and total vanillin contents of the beans, the vanillin and resin contents of the beans present in the various alcoholic extracts, and the lead number of such extracts. The values shown represent averages of duplicate samples.

TABLE 5.—*Yields of vanillin and resins obtained from vanilla beans by different methods of extraction* [1]

Lot	Method of extraction	Yield of vanillin	Proportion of total vanillin left in beans after alcoholic extraction	Yield of resins	Wichmann lead number of extract
		Percent	*Percent*	*Percent*	
A	40-percent alcohol uncorrected for moisture content of beans	2.70	3.92	1.43	0.79
B	40-percent alcohol corrected for moisture content of beans	2.73	2.85	1.50	.79
C	50-percent alcohol uncorrected	2.76	1.78	1.60	.74
D	50-percent alcohol corrected	2.76	1.78	1.77	.69
E	National Formulary method	2.72	3.20	1.30	.72

[1] Beans used for all methods contained 16.89 percent of moisture and 2.81 percent of total vanillin.

Greater concentration of alcohol yielded better vanillin extraction.

As the alcohol concentration was increased there was a small but definite increase in percentage of vanillin extracted. The increase was only from 2.70 to 2.73 percent in treatments A and B in which 40-percent alcohol corrected and uncorrected for the moisture content of the beans was used. However, the extraction made with corrected 50-percent alcohol yielded 2.2 percent more vanillin than the extraction made with uncorrected 40-percent alcohol. These results are not statistically significant but are worthy of being placed on record.

The differences in percentage between the total vanillin content of the beans and the yield obtained by the different methods of extraction varied from 0.05 in treatments C and D of corrected and uncorrected 50-percent alcohol to 0.11 in treatment A where uncorrected 40-percent alcohol was used. These differences represent in the former 1.78 percent and in the latter 3.92 percent of the total vanillin content of the beans.

Lead number and resin content of the extracts varied with the concentration of alcohol.

There was an ascending gradation in resin content of the extracts with increased alcoholic strength of the solvent. In other words, the higher the alcoholic strength, the more the resins were dissolved and appeared in the extracts.

This relationship was reversed in the lead number determinations. The lead number ranged from 0.69 in treatment D of corrected 50-percent alcohol, to 0.79 in treatments A and B of 40-percent alcohol; that is, the higher the alcoholic strength of the menstruum the lower the lead number of the extracts.

These data are in keeping with the understanding that the alcohol-soluble constituents of the beans are resins, while the water-soluble constituents are other compounds the presence of which would be indicated by the lead number.

Short maceration period of the National Formulary method affected analytical results.

The analytical results of the extraction made by the National Formulary method, treatment E, were low. The alcoholic strength of the resulting menstruum which was determined after the extract was prepared was found to be 45.2 percent. Therefore, according to the data presented in the preceding paragraphs, the analytical results

instead of being lower would be expected to be intermediate in value between the two treatments of 40-percent alcohol and those where 50-percent alcohol was used.

That such was not the case probably resulted from the length of the maceration period. In treatment E, maceration was for 12 hours in water followed by only 3 days in 95-percent alcohol which was added to the mixture of beans and water; in all the other treatments the maceration was continued over a period of 30 days.

The extracts resulting from the 40-percent alcoholic extraction both corrected and uncorrected for the moisture content of the beans, treatments A and B, were turbid, and the suspended matter did not settle even after standing for 2 months. This turbidity affected adversely the precipitation with 8-percent neutral lead acetate for the vanillin and lead-number determinations.

However, it is of importance to note that according to previous experiments, extracts made with 50-percent alcohol can be safely diluted with water to 40-percent strength without causing any considerable turbidity in the final product.

Diversity of analytical results is possible from many variables.

From this experiment and from experience with other extraction processes, it can be seen that analytical results from the same beans may be influenced by small differences in the preparation of the beans and in the extraction methods. The strength of the solvent, as already established, affects the analytical results. Furthermore, such variables as size of bean choppings and periods as well as temperatures of maceration, are factors which will affect the uniformity of analytical results. For example, maceration carried out at laboratory temperatures in Puerto Rico in January might give appreciably different analytical results from those that can be secured by the same methods of preparation and extraction at room temperatures in New York, Philadelphia, or Washington.

The action of the enzyme emulsin was tested on vanilla beans.

When vanilla beans are harvested they are not aromatic; the aroma is developed during the curing process. Although not completely established experimentally, curing is generally considered to be a fermentation process brought about by the action of enzymes on certain glucosides present in the beans.

To increase evidence concerning this process, the enzyme emulsin present in almonds was used in some laboratory fermentation tests. Locally grown vanilla beans, some entirely green and others still green but starting to mature, as indicated by the yellow color of the blossom end, were used in the experiment.

The beans were cut into fine pieces in a porcelain bowl with a mincemeat cutter. After thorough mixing, samples were weighed and placed in flasks with measured quantities of distilled water. Fifty milligrams of almond emulsin were added to each flask and the mixture was incubated at 37° to 40° C. for 2 weeks. Similar samples without added emulsin were incubated at the same temperature to serve as controls.

Table 6 shows the degree of maturity of the beans, the corresponding treatments, and the classification regarding the quality of aroma and color developed as determined by three persons unaware of the treatments but well acquainted with vanilla work.

TABLE 6.—*Action of the enzyme emulsin in the development of aroma in vanilla beans when incubated at 37° to 40° C. for 2 weeks*

Lot	Degree of maturity	Treatment	Aroma developed after 2 weeks [1]	Color developed after 2 weeks [1]
A	Beans entirely green	Incubated with 50 mg. of emulsin.	Faint	Brown.
B	Beans starting to mature; green, with blossom ends yellow.	do	Well-developed vanilla fragrance.	Dark chocolate.
C	Beans entirely green	Incubated without emulsin.	Strong, disagreeable, not vanillalike.	Pale brown.
D	Beans starting to mature; green, with blossom ends yellow.	do	Pleasant, vanillalike but less than B.	Chocolate.

[1] The indicated aroma and color of the beans began to be noticeable 3 days after the treatments were started.

Emulsin produced a fine aroma of vanilla in maturing beans.

At the end of 3 days both lots of vanilla beans with the blossom ends yellow, B and D, began to acquire a dark color and developed a fine aroma of vanilla. However, lot B, the beans containing added emulsin, had the richer chocolate color and the finer vanilla bouquet.

At the end of 2 weeks the quality of the aroma and color was still much better in the emulsin-treated beans.

Fermentation seemed to take place in all the maturing beans; however, the emulsin seemed to hasten formation of vanilla bouquet, and at the same time render it more complete in the green as well as in the maturing beans.

The control lot of beans, lot C, which were entirely green and to which no emulsin had been added, developed a strong, disagreeable odor that bore no resemblance to vanilla. Even after these beans had stood a month no characteristic aroma of vanilla could be detected in them. Furthermore, their color remained a pale brown.

Although a harsh odor was developed by treatment A, using entirely green beans incubated for 2 weeks with emulsin, still a faint aroma of vanilla could be detected. The brown color was also of a higher tone than that shown in the untreated green beans, treatment C.

Quality of aroma was correlated with maturity of vanilla beans.

As can be observed in table 6, the quality of aroma was correlated with the depth of brown color developed by all treatments. Beans in treatment B which were starting to mature when the emulsin was added, had the finest quality of aroma and the deepest color, while the entirely green beans of treatment C, where no emulsin was used, were the poorest in both aroma and color.

An added inference is that beans that are entirely green should not be harvested, because they do not later develop the aromatic constituents upon which flavorings depend. Harvesting should be delayed until the beginning of maturity, which is indicated by a yellow coloration at the apical end of the pods.

INVESTIGATIONS OF DRUG AND SPICE PLANTS

STUDIES OF QUININE PRODUCTION

United States quinine imports come from Java.

In the past few years the United States has imported quinine bark, quinine sulfate, and other salts of quinine of a total value of approximately $2,000,000 annually. The largest part of these products is imported from Java, although British India is now beginning to produce quinine to a small extent. Following experiences during the World War and more recently with the prevailing war disturbances, the opinion has been expressed that quinine should be produced under the control of the United States, or at least closer to the North American continent, to insure supplies of this essential drug at any and all times.

The wage levels for agricultural labor are extremely low both in Java and in India. It is difficult for some of the countries of the Western Hemisphere to compete with such cheap labor in the production of an agricultural crop. There is no import tax on either quinine bark or elaborated quinine sulfate in the United States; thus Puerto Rico does not have any tariff advantage in the production of this crop.

Java has capital, cheap labor, and good research.

Some crops produced by small farmers having no research advantages can frequently be produced profitably in a country of higher labor costs. even with little or no tariff protection, by utilizing research. When results of such research are applied to commercial practices they frequently may develop greater efficiency, economy, or higher-quality products. However, in Java and to some extent in British India, research in the production of quinine is apparently well advanced. Production in Puerto Rico, therefore, must start with the disadvantage of competing with the much cheaper labor in Java and India and with an absence of research results already possessed by those countries.

Quinine is not a crop for the small farmer in Puerto Rico.

It is the general impression that producers of quinine bark in Java control the output and maintain a price level which is artificial and might yield a profit even with higher labor costs. However, available information indicates that quinine is not a crop for a small farmer in Puerto Rico to undertake at the present time. The production of this tree crop is contemplated on Government land on mountains of the island, where it may also to some extent serve the purposes of soil conservation and better utilization of the land. It is conceivable that no quinine may be harvested for years from such plantings, but may be held in reserve in the event that unusual circumstances should limit supplies of quinine bark to the United States.

Such plantings also may serve as a source of seed for other Western Hemisphere countries of lower wage scales in which quinine would have better chances of profitable production.

The plantings of quinine in Puerto Rico have been made possible through the cooperation of the Division of Plant Exploration and Introduction of the Bureau of Plant Industry, which made available to this station nursery trees of four species and two hybrids of *Cinchona* and more recently supplies of seed.

Eight quinine trees at the Maricao planting produced seeds.

On December 29, 1937, a group of 107 quinine trees planted by this station in the Maricao Insular Forest were examined and 8 were found to be producing seed. These trees were for the most part survivors of the original planting of 839 trees made on November 15, 1933, together with a few of a lot of 208 trees transplanted on December 16, 1936, from the Toro Negro unit of the Caribbean National Forest at Doña Juana where they had been originally planted on June 8, 1935.

Two of the trees had reached a height of 8 feet, and there were a number over 5 feet high. Field observations indicated that these trees were susceptible to wind exposure, and the best trees occurred where there was protection from the northeast trade winds.

Figure 6 is a photograph of one of these trees planted at Maricao in 1933.

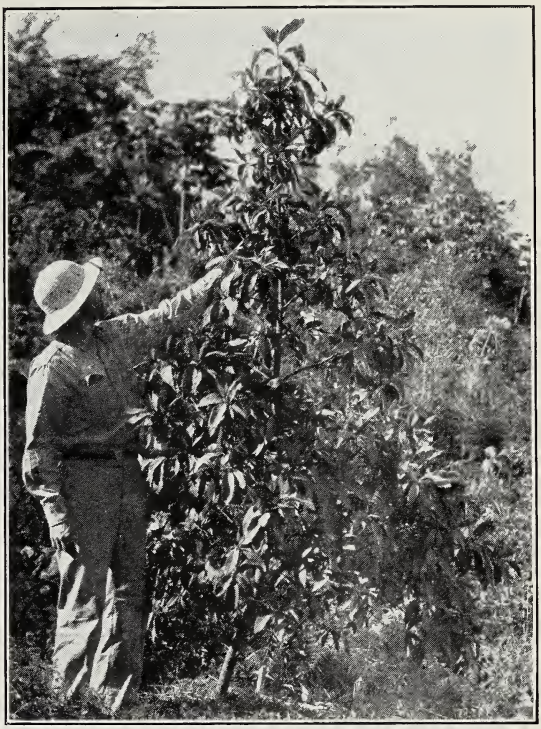

FIGURE 6.—A vigorous, 5-year-old quinine tree growing in a sheltered location in the planting at Maricao at an altitude of 2,500 feet. This tree came from a seedling which was grown in the greenhouses in Washington, D. C., and shipped to Mayaguez.

Viable seed was collected from the Maricao quinine planting.

On March 24 about one-half ounce of dried seed capsules was collected from the Maricao planting. These yielded such a small quantity of seed that grading and selection with reference to vigor and size were not practicable. Some of the seed germinated after being disinfected with calcium hypochlorite and placed on sterile agar slants, but complete germination counts were obscured and made impossible by a fungus contamination originating in the neighborhood of the seed coats. It is possible that the uneven surface of the seed coat with its many ridges was an obstacle to adequate disinfection. However, it was shown that the Maricao trees did produce viable seed.

Quinine seed was germinated readily at the experiment station.

On February 10, 1938, a package of seed of *Cinchona ledgeriana*, P. I. No. 126238, was received from the Bureau of Plant Industry. A seedbed of forest mold was prepared in the lowlands at the station, using forest leafmold as a medium for germination. The seedbed was given a formaldehyde drench to minimize fungus growth and then

a treatment with hot water to kill germinating weed seeds. The quinine seed was divided into two equal lots of 10 grams each. The first lot was treated with calcium hypochlorite and planted in an area 3½ feet wide by 9 feet long, while the second lot was left untreated and was planted in an equal area of seedbed adjacent to the first plat.

FIGURE 7.—Quinine seedbed on the lowland property of the experiment station at Mayaguez. These plants are about 6 weeks old, having grown from seed planted April 28, 1938.

Germination took place equally well in both plats, beginning in 3 weeks and continuing on through the fourth week, giving a good even stand. Damping-off did not occur among the plants from either the

FIGURE 8.—A nursery of quinine plants on the Las Mesas property of the experiment station near Mayaguez. These plants are from seed which was germinated in Washington, and the young plants shipped by steamship to Mayaguez. The nursery is at an elevation of 1,000 feet above sea level.

disinfected or the nondisinfected seed. It was estimated that 60,000 seedlings were produced from the 20 grams of seed planted. The stand of these young seedlings is shown in figure 7.

Figure 8 shows the growth made in nurseries by some of the plants shipped from Washington the previous year.

Four additional quinine nurseries were established.

On June 10, 1938, a shipment of 3,525 quinine seedlings was received from the Bureau of Plant Industry; from these 4 plantings were made in 4 different locations.

On the station grounds at Mayaguez, 561 plants were set out on June 10 and 11; at the Castañer farm near Adjuntas, 2,193 on June 13 and 14; at El Semil near Villalba, 131 on June 15; and on the station property on Las Mesas 640 were planted on June 15. The actual planting was expedited by preparing beds and shelters in the different locations before the arrival of the shipment. For the beds on the station grounds at Mayaguez, leafmold was mixed with garden soil, 1 part of soil to 2 parts of leafmold; at Castañer a black soil rich in organic matter was used; at El Semil, porous clay was mixed with an equal part of leafmold; and at Las Mesas pure forest mold was used.

It was noted upon arrival that a number of the plants were dead and others injured. A total of 2,432 plants, or about 69 percent, arrived in apparently good condition; 474, or about 13.5 percent, were badly injured; and 619, or about 17.5 percent, were dead.

PRELIMINARY STUDIES OF CINNAMON PROPAGATION

The United States imports most of its cinnamon from Ceylon.

Commercial cinnamon bark is obtained from trees of *Cinnamomum zeylanicum*, a native of southern India; most of the imports of the United States come from Ceylon, although it is also produced in Java, southern India, the Seychelle Islands, Brazil, and several of the islands of the West Indies. There is no import tariff on cinnamon bark in the United States, but apparently it is a crop that has not had much advantage of research. When cinnamon bark is ground or otherwise advanced in preparation, it is subject to an import tariff of 5 cents per pound.

In addition to the direct use of cinnamon for flavors, an oil is obtained from the bark which contains cinnamic aldehyde, principally, and eugenol. Eugenol is the principal constituent of the oil obtained from the leaves, while camphor is present in the roots. According to the Tariff Act of 1930, eugenol and these other compounds have an import duty of 45 percent ad valorem, which does not apply to oils produced in Puerto Rico. Crude camphor has an import tariff of 1 cent per pound.

Cinnamon trees grow well in the fairly wet areas of the coffee districts in Puerto Rico. For this island it would seem logical that in order to benefit from the slight tariff advantages available, cinnamon bark and oils should be advanced in preparation as much as possible, which would also have the advantage of increasing employment in such industrialization. Cinnamon products would pay considerably less freight per dollar value than would coffee.

The industry is a small one, the total value of cinnamon bark imported into the United States averaging about $100,000 annually in recent years. The value of imports of cinnamon oils has varied from $115,000 in 1935 to $191,000 in 1937.

Two species of cinnamon exist in the station collection.

When specimens were submitted to E. D. Merrill of Harvard University, it was found that the cinnamon plants introduced a number of years ago into the station collection under the name of *Cinnamomum zeylanicum* Nees. were improperly labeled and were not the cinnamon of commerce as was at first supposed. These plants were identified by Dr. Merrill as *C. burmanni*, which appears in most herbaria as *C. pedunculatum*.

Propagating material of the commercial cinnamon (*Cinnamomum zeylanicum*), as determined by Dr. Merrill, has recently been obtained and established in the station collection at Mayaguez.

Cinnamomum burmanni produces one of the cassia barks of commerce.

The principal cassia bark of commerce comes from the Chinese cinnamon (*Cinnamomum cassia*). However, trees of *C. burmanni* also yield cassia barks which enter into commerce. *C. burmanni* is native in Sumatra and Java and has been cultivated in Sumatra. Cassia barks are used in the preparation of drugs and have larger proportions of essential oils than *C. zeylanicum*. The value of oils of the cassia barks imported into the United States in recent years has varied from $116,000 to $230,000 annually.

Treatments with indolebutyric acid shortened rooting period of Cinnamomum burmanni.

Existing methods of propagating cinnamon trees are slow, and it is difficult by these methods to reproduce a large number of trees from a small amount of material. Three experiments were conducted in which cuttings of *Cinnamomum burmanni* were treated with various concentrations of indolebutyric acid in water to observe any stimulating effects that these solutions might have on rooting.

These experiments with *Cinnamomum burmanni*, of which considerable material was on hand, were intended to indicate roughly the limits of concentrations which it might be advisable to use later with the more limited supply of cutting wood of *C. zeylanicum*. Even if the information obtained should prove not to be applicable to *C. zeylanicum*, it would still be useful since *C. burmanni* has commercial possibilities.

The first two experiments indicated that cuttings from 2- to 3-year-old twigs were superior to those from older or younger twigs and also that better response might be obtained from treatment with indolebutyric acid solutions stronger than 160 parts per million.

Treatment with 0.064-percent indolebutyric acid induced optimum response.

A third experiment was undertaken to test the effect of more concentrated solutions than were used in the first two experiments. To obtain solutions of indolebutyric acid in excess of 160 parts per million the water had to be warmed before adding to it the alcoholic solution of the acid. This made it possible to limit the alcoholic content of the final solutions to a negligible 1 percent. When the solutions were cooled previous to treating the cuttings, no precipitation of the acid took place. In all other respects the technique and materials were similar to those used in previous experiments. Fifteen cuttings were subjected to each treatment, which in every case lasted for 16 hours.

In table 7 are shown the number of cuttings that had rooted 53, 67, and 77 days after treatment.

TABLE 7.—*Effect of treatments with concentrated solutions of indolebutyric acid on the rooting of Cinnamomum burmanni cuttings*

[Cuttings were treated on Apr. 1, 1937]

Concentration of indolebutyric acid (p. p. m.)	Cuttings treated	Cuttings rooted after—			Concentration of indolebutyric acid (p. p. m.)	Cuttings treated	Cuttings rooted after—		
		53 days	67 days	77 days			53 days	67 days	77 days
	Number	*Number*	*Number*	*Number*		*Number*	*Number*	*Number*	*Number*
0 (Check)	15	0	0	0	320	15	7	9	9
80	15	0	2	3	640	15	11	13	14
160	15	2	4	8					
240	15	6	10	11	Total	90	26	38	45

In this experiment, the cuttings were first examined 44 days after treatment but no roots were observed at that time. The small size of all of the roots observed at the next examination, 53 days after treatment, indicated that they had been formed for only a few days and that there had been but a small lapse of time between the incidence of roots among cuttings treated with the 640 parts per million solution and the incidence of roots among cuttings treated with the 320 and 240 parts per million solutions.

It is readily observable from table 7 that the three strongest concentrations, 240, 320, and 640 parts per million, rated closely in ability to stimulate rooting. It may be concluded from this and from inferences which may be made from the observations on incidence of rooting, that the solution containing 640 parts per million (0.064 percent) induced near-optimum response.

When examined statistically by analysis of variance, the data of this experiment showed a high degree of significance. F values for "between treatment" of 8.13, 16.38, and 11.87 were obtained for the three respective sets of data corresponding to the three intervals at which readings were taken. These values are indicative of almost infinite significance since for the degrees of freedom concerned an F value of only 3.29 is needed to give odds of 99 to 1 that the differences between treatments were not a result of chance alone.

PRELIMINARY STUDIES OF CLOVE AND NUTMEG PROPAGATION

Preliminary studies are being made of the propagation of cloves.

The clove tree (*Eugenia aromatica* (*caryophyllata*)) is native to the Molucca Islands in the East Indies. Cloves of commerce are the dried immature flower buds of the tree. During the past few years, the United States has imported clove and clove stems valued at approximately half a million dollars a year; most of the clove imports come from Madagascar and British East Africa, although smaller quantities come from the Netherlands East Indies, the British West Indies, and some of the French colonies. There is no import tax in the United States on clove or clove stems. When cloves are advanced in preparation by grinding, there is an import tariff of 6 cents per pound and 5 cents per pound on ground clove stems.

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Upon distillation, cloves yield approximately 17 percent by weight of oil, and stems and leaves lesser amounts. The chief constituent of this oil is eugenol. There is an import tariff in the United States on clove oil of 12½ percent ad valorem. Clove trees are grown under climatic conditions similar to those of the coffee districts of Puerto Rico and so may be said to be a crop which is adapted to hillside cultivation with little loss of soil from erosion.

Young seedlings are affected by a collar rot that has been destructive but which by analogy with similar troubles should yield to seed and seedbed disinfectant treatment.

Nutmegs and mace come from the Netherlands Indies and British West Indies.

The nutmeg tree (*Myristica fragrans*) yields two important spices, the nutmeg itself and mace; it is a native of the Moluccas, or at least was first known from there. The United States in the past few years has imported most of its nutmegs and mace from the British West Indies and Netherlands East Indies; almost all such imports are unground and unprocessed. The value of nutmeg imported into the United States was $504,000 in 1935, $465,000 in 1936, and $642,000 in 1937. The value of imports of mace during the same years was $294,000, $311,000, and $373,000, respectively. There is no customs tax imposed on imports of either unprocessed mace or nutmegs entering the United States. Mace when ground has an import duty of 8 cents per pound and ground nutmegs a duty of 5 cents per pound.

The nutmeg tree thrives in an area of abundant moisture such as occurs throughout the coffee districts of Puerto Rico. Preliminary studies have been made of the germination of seeds, which lose their viability rapidly with age. Young seedlings are also subject to a collar rot that has been destructive.

Nutmeg trees are also a crop adapted to hillside cultivation and afford some protection against soil erosion. Neither clove nor nutmeg production seems to have benefited much as yet from agricultural research. Spice crops as a class have the advantage of a low ratio of freight costs to dollar value.

PRELIMINARY STUDIES OF GINGER PRODUCTION

Small tariff advantage is available on elaborated ginger.

A large part of the ginger imported into the United States comes from China and Hong Kong, both as the unground and unpreserved root and as candied or otherwise preserved ginger. There are also considerable importations from Jamaica, British India, and British West Africa. Ginger is obtained from the rhizomes of a fleshy perennial (*Zingiber officinale*) which is a native of tropical Asia. Ginger production is apparently an industry of small farmers who have had little advantage of research.

Ginger root not preserved or candied but ground has an import duty in the United States of 5 cents per pound. Ginger root candied or otherwise prepared or preserved has an import duty of 20 percent ad valorem. Unground ginger root, not candied or preserved, has no import tax on entering the United States.

Ginger has grown well at the experiment station at Mayaguez, where there is adequate rainfall. The heavy clay soils at the station,

however, seem somewhat too compact for the best development of the rhizomes, and parts of the island in which there are looser soils but adequate rainfall would seem more desirable for this crop. Ginger is not a crop adapted for production on hillsides or sloping land, since in excavating the rhizomes at harvesttime the soil is loosened and made susceptible to erosion. It is logical that, if attempts are made to produce ginger, advantage should be taken of the small tariff on the ground ginger or candied preserves, which also will employ some labor in such industries.

Ginger rhizomes undergo a rest period during the dry season.

In Puerto Rico, the leaves of ginger in the field die back in January or February, and it is at this time that the rhizomes are harvested. Often a ratoon crop is grown from pieces of rhizome that remain in the field after harvest, but the common and most desirable practice from the standpoint of getting good quality is to set out a new planting with rhizome seed pieces which have been stored for a short interval after harvesting. Ginger is usually planted in March, April, or early May when the rainy season begins. Large entire "hands" that have undergone a dry-storage period of 3 to 5 months are planted. Large hands are used because presumably they sprout stronger and sooner than would be the case with smaller pieces. With favorable weather ginger planted in this way sends up initial sprouts in 5 to 6 weeks. About 4,000 pounds of ginger seed pieces are planted to the acre. The yield per acre with the present practice seldom exceeds 10,000 pounds. Since the ratio of yield to weight of roots planted is so low, the use of smaller seed pieces that produce plants of satisfactory vigor is indicated.

If ginger is dug up while it is growing and then replanted, the rhizomes will remain dormant and will not sprout so long as the soil remains moist. To resume growth the rhizomes ordinarily undergo a dry period of about 60 days. Following the dry period, the soil should remain moist for a continuous period of 5 to 6 weeks during which time shoots and roots will be regenerated. The soil should then remain sufficiently moist to maintain growth during a normal growing season. A prolonged drought will cause the leaves to wither and will throw the rhizomes into a dormant state, when again they will require about 60 days of dry conditions followed by moist conditions in order to resume growth.

Although the length of the dry resting period of ginger is roughly about 60 days, this is an arbitrary figure depending on a large number of factors. Moreover, a longer period seems to break the dormancy more thoroughly. It appears that rhizomes assume varying ability to regenerate a greater or lesser number of new shoots depending on the thoroughness with which the dormancy is broken. Thus when a given hand of ginger in which the rest period has been thoroughly broken is divided into small pieces, each piece would be more likely to sprout than would be the case if the rest period had been but partly broken.

Treatment with ethylene chlorohydrin shortened the rest period of ginger rhizomes.

With a view to developing a method whereby small pieces of ginger will sprout evenly and soon after planting, a small experiment was

undertaken to test the effects of treatment of the seed pieces with ethylene chlorohydrin.

Lots of 100 seed pieces, each about 1 inch long, were exposed in fruit jars for 3 days to concentrations of the gas from 40-percent ethylene chlorohydrin varying by tenths from 0 to 1 milliliter of the liquid per liter of air space. The seed pieces were dug from plants which still bore green leaves on November 19, 1937, the day the treatments were started.

The data from this experiment were statistically significant and indicated that the strongest concentrations induced the best response. One milliliter of 40-percent ethylene chlorohydrin per liter of air space was the strongest concentration used. The obvious inference is that stronger concentrations may be even more effective in breaking the dormancy of ginger rhizomes.

Investigations of drug and spice crops were conducted by William Pennock, assistant agronomist.

COFFEE INVESTIGATIONS

Columnaris variety continued to outyield West Indian variety.

In continuing the varietal experiment with coffee planted by T. B. McClelland of this station in 1931 and harvested every year since 1934, much valuable data on the comparative yields of the West Indian and Columnaris varieties of *Coffea arabica* have accumulated. The West Indian is the variety of Arabian coffee most commonly grown in Puerto Rico; the Columnaris was introduced by the station from Java some years ago. This experiment, which is still running, consists of seven replicated plats of each variety, with six to eight trees to each plat. The planting is located in the grounds of the station at Mayaguez on what is known as Catalina clay, a soil type representative of a large part of the coffee districts of the island. With the close of the 1937 picking season information on the yields for four consecutive crops is at hand. The harvest data on a per-acre basis for all four crops are shown in table 8.

TABLE 8.—*Comparative yields obtained from the West Indian and Columnaris varieties of Coffea arabica in variety tests at the experiment station, 1934–37* [1]

Variety	Trees	Yields per acre								
		1934		1935		1936		1937		Total marketable coffee, 4 crops
		Fresh berries	Marketable coffee	Fresh berries	Marketable coffee	Fresh berries	Marketable coffee	Fresh berries	Marketable coffee	
	Number	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
West Indian	50	1,691	372	2,800	617	2,131	468	3,937	712	2,169
Columnaris	50	1,696	373	5,100	1,122	8,762	1,927	7,375	1,331	4,753

[1] Experiment planned 1931 by T. B. McClelland; harvested 1934 by Carlos Esteva, harvested 1935–37 by Jaime Guiscafré Arrillaga. Seven replicated plats of each variety with 6 to 8 trees per plat.

Columnaris variety has produced 119 percent more coffee than West Indian variety.

Table 8 shows that the Columnaris variety did not produce as well in 1937 as in the previous year. The West Indian variety, however,

had its best year in 1937; nevertheless, the Columnaris variety outyielded it almost 2 to 1 in the 1937 harvest. The total yield of marketable coffee per acre for four crops of the Columnaris variety was 119 percent more than that of the West Indian variety. All the differences in yield were so great as to be statistically significant.

A small proportion of coffee flowers reached mature berry stage.

The study begun last year to determine the percentage of coffee flowers that would set and produce mature berries was continued during 1937 and enlarged to include the Columnaris variety for comparison with the West Indian variety.

In this study the 50 trees of each of these 2 varieties in the variety experiment just described were used; all trees were on the same kind of soil, and the topography and exposure to sun and shade were uniform throughout the whole planting. On these 100 trees 150 lateral branches of the same age located at approximately the same height from the ground were selected and labeled for study. The flowers, developing berries, and ripe berries were counted at the times when they naturally occurred.

A summary of the results of this study are shown in table 9.

TABLE 9.—*Summary of flowering and fruiting of selected branches of the West Indian and Columnaris varieties of Coffea arabica during the 1937 season*

Variety	Flowers formed	Flowers that did not reach mature berry stage		Berries harvested	
	Number	*Number*	*Percent*	*Number*	*Percent*
West Indian	13,687	10,167	74.28	3,520	25.72
Columnaris	15,307	12,807	83.67	2,500	16.33

Only 16.33 percent of flowers of Columnaris variety developed into mature berries.

Of the 13,687 flowers counted for the West Indian variety only 25.72 percent developed into mature berries; 74.28 percent of the flowers of this variety either failed to set or the developing berries abscised before reaching the mature berry stage. With the Columnaris variety the loss was even greater; 83.67 percent of the flowers were lost, with only 16.33 percent reaching the mature berry stage.

The proportion of the flowers formed by given dates for the two varieties is shown in table 10.

TABLE 10.—*Time and extent of flowering on selected branches of West Indian and Columnaris varieties of Coffea arabica at different times during the 1937 season*

Variety	Proportion of flowers opened by—								
	Feb. 6	Mar. 5	Mar. 9	Apr. 13	Apr. 14	May 4	May 5	June 1	June 6
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
West Indian	3.61	29.63	----------	38.50	- -	43.48	- - -	100.00	------
Columnaris	0	---------	33.10	---------	50.72	---------	54.84	-------	100.00

A large proportion of coffee blossoms opened during the last month of blossoming period.

Of special interest is the fact that only about 40 percent of the flowers of the West Indian and little more than 50 percent of those

of the Columnaris variety had opened during February, March, and April, a heavy period of blossoming during May accounting for almost half of the total number of blossoms of the Columnaris and for about 60 percent of the blossoms of the West Indian.

Similar information is given in table 11 for the proportion of mature berries harvested by given dates. Whereas the blossoming period extended over a period of about 120 days the harvest of both varieties was completed in less than 90 days after the first mature berries were harvested.

TABLE 11.—*Proportion of berries reaching harvest stage on selected branches of West Indian and Columnaris varieties of Coffea arabica at different dates during the 1937 season*

Variety	Proportion of mature berries harvested by—							
	Sept. 7	Oct. 4	Oct. 15	Nov. 2	Nov. 4	Nov. 19	Nov. 20	Dec. 2
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
West Indian	3.04	12.07	38.49	74.83	----------	95.37	----------	100.00
Columnaris	0	4.16	14.88	----------	61.92	----------	84.84	100.00

The flowering and harvest relationships of the two varieties are shown graphically in figure 9. Assuming that the berries maturing

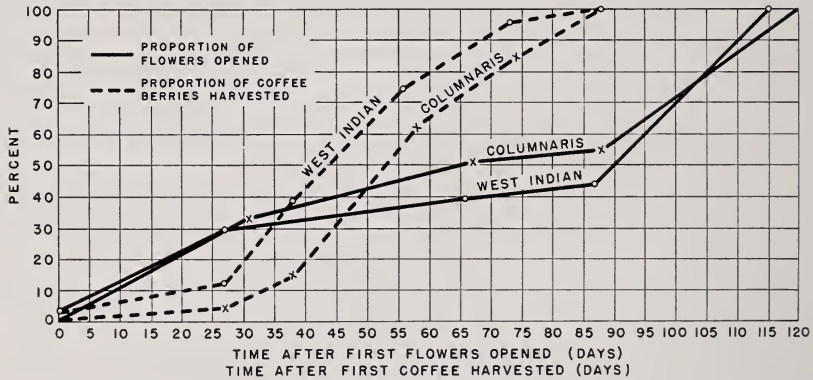

FIGURE 9.—Cumulative percentages of flowering after the opening of the first flowers, and of berries matured and harvested after the first picking, on selected branches of the West Indian and Columnaris varieties of Coffea arabica during the 1937 season.

early in the season required about the same number of days to reach maturity as those ripening in the latter part of the season, the slope of the harvest curves and that of the flowering curves indicate that those flowers opening during the first month of the flowering period failed to set well. Furthermore, practically all of the flowers opening during the last month of the flowering season were a total loss insofar as berry production was concerned. By far the largest proportion of the mature berries harvested developed from flowers opening during March and April, the second and third months of the blossoming season.

The larger yield of the Columnaris variety was due to a larger crop of flowers.

Of the flowers that failed to set and the developing berries that dropped before reaching maturity, practically all were lost before the end of the first week in July. Less than 6 percent of the total loss in the West Indian variety and less than 3 percent of that in the Columnaris variety occurred after July 7.

Both varieties of coffee produced berries of about the same size. Since the percent of flowers developing into mature berries was smaller with the Columnaris variety than with the West Indian, it necessarily follows that the greater yield of the Columnaris variety recorded in table 8 must have been the result of a much heavier crop of flowers.

The coffee work at this experiment station continued in cooperation with the personnel of the experiment station of the University of Puerto Rico. Jaime Guiscafré Arrillaga and Luis A. Gomez have represented the University Experiment Station in the cooperative coffee research just reported.

ESSENTIAL-OIL INVESTIGATIONS

Some essential-oil plants are well adapted to the coffee districts.

In the search for crops that may give higher returns per acre than coffee and will be well adapted to the soils and climate of the coffee districts, some of those producing essential oils have been given consideration. The essential oils of lemon, orange, and peppermint have an import tariff of 25 percent ad valorem according to the Tariff Act of 1930. Essential oil from eucalyptus has an import duty of 15 percent ad valorem and from cloves, patchouli, and sandalwood a tariff of 12½ percent ad valorem. Oils from grapefruit have an import duty of 25 percent ad valorem from all countries except Cuba, which pays an import duty of 10 percent. Most other distilled or essential oils have no import duty on entering the continental United States, and farmers of the island would be in direct competition with cheap agricultural labor of some of the other tropical countries.

However, essential oils that are duty-free in the unelaborated state receive some tariff protection when they are advanced in preparation. For example, oil of lemon grass has no import duty, but citral, which constitutes 50 to 80 percent of lemon-grass oil, has an import duty of 45 percent ad valorem. When such materials are further elaborated into perfumes, Cologne water, toilet water, and other forms of perfumery, there is an import duty of 40 cents per pound and 37.5 percent ad valorem. As in the case of spices, the more the agricultural product is elaborated and refined the more tariff protection it receives. It is logical, therefore, for such products to be processed in the island, for not only do they thus obtain greater tariff protection against countries employing cheap coolie labor, but also such added processing yields greater income per acre and more employment. Puerto Rico may have another advantage of undetermined value in the way of research in the production of these essential oils, their derivatives and products.

The value of the imported essential oils consumed in the United States is not great—$4,750,000 in 1936 and $5,500,000 in 1937.[2] It is

[2] UNITED STATES BUREAU OF FOREIGN AND DOMESTIC COMMERCE. TOILETRY RAW MATERIAL IMPORTS AT PEAK LEVELS. U. S. Bur. Foreign and Dom. Com. World Trade Notes on Chem. and Allied Prod. 12:362–363. 1938.

conceivable that the income to Puerto Rico from exports of essential oils might easily exceed that from coffee. The value of oils of citronella and lemon grass imported into the United States during the years 1932–36 varied between $500,000 and $700,000. Ilang-ilang varied between $48,000 and $48,261. Musk seeds varied from $10,000 to $70,000. The values of imports of perfume and perfume materials into the United States are much larger.

During the fiscal year investigations were limited mostly to those essential oils which could be extracted by steam distillation.

ILANG-ILANG OILS

Ilang-ilang trees grow well in Puerto Rico.

Ilang-ilang oil comes from the flowers of the ilang-ilang tree (*Cananga odorata*) which is indigenous to Burma and distributed in

FIGURE 10.—Fully developed ilang-ilang flowers showing length of the petals.

southern Asia, Reunión, Java, and the Philippine Islands. While this tree grows well in Puerto Rico, until recently it has been used only as an ornamental and confined mostly to the western part of the island. However, a few trees are also found growing in the dry sections of the island, particularly on the south coast near Ponce.

In an orchard planted at the experiment station the trees were bearing a small crop of flowers when only 18 months old. Flowers have been produced almost the year around, but the largest crop is in the spring. A few twigs bearing typical, fully developed flowers are shown in figure 10. Cananga oil, as the undifferentiated oils of ilang-ilang are known commercially, now comes principally from the Philippines and the islands of Comoro, Nosse Bé, and Reunión, near Madagascar.

Maceration of ilang-ilang petals decreased oil yield but increased aroma.

Maceration, or soaking, in water is sometimes used as a preliminary treatment before extracting the essential oils from various plants by steam distillation. During the past year an experiment was conducted in order to observe the effect of such maceration on the yield and quality of essential oil from ilang-ilang petals. A quantity of fully ripe flowers was harvested in the early morning, and later the same day the petals were cut into pieces about one-fourth of an inch long. The cut petals were divided into three samples of 250 grams each and the separate samples were packed to a uniform density by pressing under a 100-pound weight. Lot A was not macerated and was used as a check, lot B was macerated for 24 hours, and lot C for 48 hours. The check lot was steam-distilled for 6 hours immediately following cutting; the other two samples were distilled in their own maceration water for the same length of time following the termination of their maceration periods. The same still was used for all samples. At the end of the 6-hour distillation period a yield of 1.08 percent of oil was obtained from check lot A, 1.07 percent from lot B, and 0.93 percent from lot C.

When the test was repeated with samples weighing 100 grams each instead of 250 grams, practically the same yields were obtained. Lot A, not macerated, yielded 1.08 percent of oil as before; lot B, macerated for 24 hours, yielded 0.99 percent; and lot C, macerated for 48 hours, again yielded the least, 0.765 percent of oil.

It is evident that the greatest yield of oil was obtained from the petals in unmacerated lot A. Although the maceration that the other two lots received decreased the amount of oil obtained from them, these oils were superior in quality and had a more suave and lasting aroma than did those from check lot A. However, this improvement in quality was not considered sufficient to compensate for the labor and expense of maceration or the resulting decrease in quantity.

Ilang-ilang flowers yielded 2.3 percent of cananga oil.

Cananga oil of high quality and in an appreciable amount was obtained from five lots of ilang-ilang petals by steam distillation for 12 hours. Fully ripe flowers cut into ¼-inch pieces were used, and the lots ranged in weight from 300 to 425 grams each. The petals were not macerated but were distilled immersed in water. A yield of cananga oil of approximately 2.3 percent was obtained. This compares favorably with a yield of from 1.5 to 2.5 percent usually obtained in commercial work in other countries.

Fractional distillation periods were determined for three grades of ilang-ilang oil.

After a 190-gram sample of fully ripe ilang-ilang petals had been steam-distilled for 2 hours it was noted that the droplets of oil coming through the condenser, instead of uniting directly with the previous floating distillate, would fall to the bottom of the receiving flask. As this indicated that an oil of a different density was coming through, it was considered as the end of the first fraction in the distillation of this oil. After another 2 hours of distillation the milkiness that was formerly present in the distillate disappeared, and the oil coming through remained on the top of the distillate in the receiving flask.

This indicated the distillation of an oil of still a different density and was considered as the end of the second fraction. Distillation was continued for 3 hours more, making 7 hours in all, the last 3 of which may be considered as the distillation period of the third fraction. A yield of 1.20 percent of oil was secured in the first fraction, 0.75 in the second, and 0.50 in the third.

The oil obtained in the first fraction of the distillate was superior to the other two, since it contained the most volatile and aromatic constituents of the flower and, for this reason, would be the most desirable for expensive perfumes. The second fraction was not so desirable for high-quality perfumes as the first, because of the presence of less volatile oils of lower aromatic value. The last fraction was so much inferior to the first and second in aroma and other qualities that to be marketable it would have to be blended with one or both of the other fractions and then used only in inexpensive perfumes.

Fully ripe petals of ilang-ilang flowers gave the highest yield of oil.

A quantity of ilang-ilang flowers of different ages was harvested in the early morning and immediately separated into three groups. One group contained the petals of unripe flowers that had short, green petals; the second group consisted of petals of semimature flowers with greenish-yellow petals developed to full length; and the third group contained petals of fully ripe flowers with yellow, fully developed petals rich in aroma. One hundred and ninety grams of petals taken from each group of flowers were then steam-distilled separately and the resulting oils were divided each into three different fractions, as in the foregoing test. Table 12 shows the yield obtained in each fraction from each lot of petals.

TABLE 12.—*Fractional yield of essential oil from 190-gram samples of ilang-ilang petals of different ages*

Maturity of petals	Oil content			
	First fraction	Second fraction	Third fraction	Total
	Percent	*Percent*	*Percent*	*Percent*
Immature	0.45	0.25	0.10	0.80
Semimature	.50	.45	.20	1.15
Fully mature	1.20	.75	.50	2.45

The yield of oil in each of the three fractions was much greater from the fully ripe petals than from the petals of either of the other two less mature lots; these oils were also highest in quality. The yield of oil obtained in the first fraction of each age of petals was greater and the quality higher than that in the other two fractions.

The central parts of ripe ilang-ilang flowers yielded 0.34 percent of oil.

During the preparation of the above experiment it was noted that not only the petals but also the central parts of the fully ripe flowers gave off an aroma. Therefore, such central parts were separated, finely crushed, and steam-distilled to ascertain their oil content.

It was found that 175 grams of the crushed central parts yielded 0.6 milliliter of oil. This is equal to a yield of 0.34 percent of the original weight used, and indicates the advisability of including the central parts of ripe ilang-ilang flowers in commercial distillations.

LEMON-GRASS OIL

Lemon grass has not been grown commercially in Puerto Rico.

The oil of lemon grass (*Cymbopogon citratus*) is employed largely in the preparation of citral, which is the basis for the manufacture of ionone, a base for a synthetic violet perfume.

Although the grass grows well in Puerto Rico, as can be seen in figure 11, it has been planted in only a few places and then as a door-yard or specimen plant in gardens. The country people sometimes clean their teeth with the leaves and claim that the oil liberated in the process has some germicidal value. The green leaves are also used to some extent in medicinal teas and other beverages, and the dried leaves are sometimes employed in the home manufacture of hammocks. Until the present investigations were undertaken by this station, little was known of the oil-yielding possibilities of the locally grown grass.

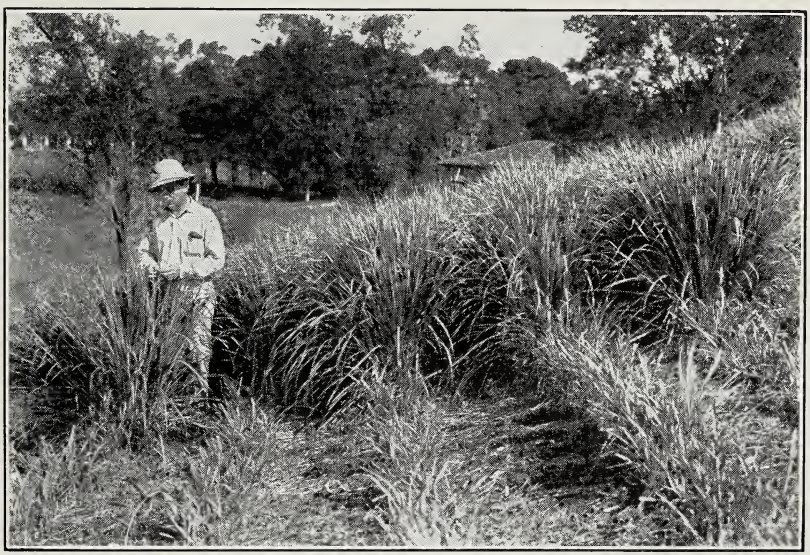

FIGURE 11.—Three-month-old lemon grass (*Cymbopogon citratus*) in experimental plat at the station. This grass has attained full development and is ready for distillation. In the foreground are shown ratoons growing from stools that have been recently harvested. This grass contains an essential oil which is used in the manufacture of a synthetic violet perfume.

Since lemon grass can be grown on steep hillsides that would have little other use and is a crop of great aid in checking soil erosion, it is well suited for limited areas in this island. Moreover, with the favorable yield of oil found thus far and the protection of the present moderate tariff on citral it may be a profitable crop in some parts of the island now devoted to coffee production.

Analyses of two crops of lemon grass showed relatively high yield of citral.

Two full crops of lemon grass were harvested during the present year from a plat 0.0149 acre in area on the station grounds at Mayaguez. This plat is located on a hillside of Catalina clay typical of

many hillsides of the island. In the first of these two crops 361.75 pounds of grass, equal to 24,279 pounds per acre, were harvested from January 2 to 17; in the second crop 288 pounds, or 19,329 pounds of grass per acre, were harvested from April 15 to 20. The age of the grass at each harvest was between 3 and 4 months. It is estimated that four crops per year, one approximately every 3 months, can be harvested without replanting, as the grass ratoons easily.

Representative samples of grass from both of the above crops were analyzed immediately following the harvests. An infestation of the yellow sugarcane aphid (*Sipha flava* Forbes) developed in the plat before the first harvest was started; therefore, except as noted in the following discussion, at least some blades of grass in every sample used in these analyses had been fed upon by this insect.

Preparatory to distillation the samples were run through a feed cutter which cut the grass into pieces about one-fourth of an inch long. After the freshly cut pieces were thoroughly mixed to insure homogeneity, each sample was divided into two equal lots which in successive charges were packed uniformly in the steam-distillation retort. Each charge was distilled for 1 hour 40 minutes. Two distillations were thus made of every sample. The water left in the retort and separated from the oil after the first distillation was used for the second distillation. In this way the possible error of not measuring some dissolved oil was minimized. In every case the second distillation gave a higher yield of oil than the first, an indication that most of the oil dissolved in the water left after the first distillation was recovered in the second.

Since citral is the most valuable constituent of lemon-grass oil, the amount of this compound in the oil obtained from all samples was determined. This was done by the use of Kleber's official method, which is based on the ability of an aldehyde, in this case citral, to form a hydrazone with phenyl hydrazine. Three samples of oil of each harvest, all of equal weight, were thus analyzed for citral and the results averaged. Since specific gravity is often used by buyers as an indication of citral content, the specific gravity of the oil obtained was determined in each case.

In table 13 are given the yield of oil, its specific gravity, and the citral content, obtained from field-run samples of the lemon grass of the first two harvests of the 1938 growing season.

TABLE 13.—*Yield of essential oil and citral from lemon grass harvested in January and in April 1938*

Harvest	Weight of sample	Yield of oil		Analyses of oil		Yield of citral
				Specific gravity	Citral content	
	Pounds	*Grams*	*Percent*		*Percent*	*Percent*
January	10	13.826	0.306	0.9216	82.63	0.253
April	10	22.300	.350	.8836	77.48	.271

The sample of grass from the second, or April, harvest showed a higher yield of oil than that from the January harvest, and, in spite of the comparatively lower citral content of the oil from the second

harvest the amount of oil obtained was sufficiently great to result in a slightly higher yield of citral. These yields can be compared with yields of from 0.24 to 0.40 percent of oil reported as usually obtained from this grass grown in other countries.

Tin caused no change in ilang-ilang and lemon-grass oil.

In considering the metals that might be used in the construction of stills for essential oils and of other apparatus used in perfume work, the effects of three metals on ilang-ilang and lemon-grass oils and the effect of these oils on the metals themselves were recorded during the year. Sheets of copper, iron, and tin were cut into small pieces and placed in glass containers holding 3 milliliters of each oil. The containers were then set aside and agitated occasionally for 1 month. At the end of this time the metals were weighed and the color and aroma of the oils noted. Table 14 shows the percent loss in weight of each metal used and the changes observed in the oils.

TABLE 14.—*Effects of copper, iron, and tin on ilang-ilang and lemon-grass oils*

Oil		Metal				Observations
Kind	Amount	Kind	Weight	Loss in weight		
	Milliliters		*Grams*	*Grams*	*Percent*	
Ilang-ilang	3	Copper	0.290	0.071	24.48	Color turned to a pale green; no change in aroma.
		Iron	.048	.048	100.00	Color changed to a deep brown, and a precipitate formed; aroma changed completely, rendering oil of a poor quality.
		Tin	.786	.038	4.83	No noticeable change in color or aroma.
Lemon grass	3	Copper	.174	.073	41.95	Color changed to a brilliant green; no change in aroma.
		Iron	.103	.007	6.80	Color changed to a deep brown accompanied by the formation of a precipitate, aroma changed.
		Tin	.790	.000	.00	No noticeable change.

The ilang-ilang oil, which had a delicate aroma to start with, was affected more by each metal than was the lemon-grass oil. Iron was particularly deleterious to the ilang-ilang oil and was completely dissolved in it; the color of the oil was changed to a deep brown and the aroma was almost completely destroyed. Iron also discolored and changed the aroma of the lemon-grass oil. Copper, however, did not appear to be nearly so harmful to either oil, although considerable quantities were dissolved and the oils were changed to a green color. Tin, on the other hand, suffered little decomposition in the ilang-ilang oil and none in the lemon-grass oil and did not produce any noticeable change in the color or the aroma of either oil.

AMBRETTE PRODUCTION AND EXTRACTION

Warm water improved germination of ambrette seeds.

The seeds of the musk mallow (*Hibiscus abelmoschus*) yield an essential oil, ambrette, which is used extensively in perfumes. A difficulty in the propagation of this plant is the slowness with which

the seeds germinate. In an attempt to find some method of hastening germination an experiment was conducted with seeds of the ambrette plant.

In this experiment there were 360 seeds in each treated lot and the check; the treatments were immersion for 1, 6, 12, and 24 hours, respectively, in water which at the beginning was not too warm for exposure of the fingers without discomfort, insuring absence of coagulation of embryo proteins. Immediately after being removed from the water 180 seeds of each lot and the check were planted in each of two replicated plats in the open, each plat having 3 rows and having been uniformly fertilized with a 12–6–5 fertilizer. The percentages of seeds germinating, as judged by the appearance of the plants through the soil at the end of 7, 15, and 30 days, are recorded in table 15.

TABLE 15.—*Percentages of ambrette seeds germinating in specified periods after treatment with water*

Lot	Time in water [1]	Germination at the end of—			Lot	Time in water [1]	Germination at the end of—		
		7 days	15 days	30 days			7 days	15 days	30 days
		Percent	*Percent*	*Percent*			*Percent*	*Percent*	*Percent*
A	1 hour	15.0	21.4	22.8	D	24 hours	4.7	6.9	9.4
B	6 hours	35.0	46.1	49.1	X	Check	8.0	8.9	10.6
C	12 hours	41.1	54.4	56.2					

[1] 360 seeds received each treatment.

It is evident that the 12-hour water treatment gave the best results, a higher percentage of germination resulting from this treatment than from any of the others. Since fewer seeds germinated among those that were soaked for 24 hours, treatment D, than those that received the 1- to 12-hour treatments, it is apparent that this long period in water was detrimental.

Immersion in sulfuric acid hastened germination of ambrette seeds.

Shortly after the warm-water experiment was started, another experiment with ambrette seeds was begun in which abrasion with sand and soaking in concentrated sulfuric acid were used in an effort to find a treatment that would more satisfactorily hasten germination. Four lots of 500 seeds each were given different treatments. Lot A was shaken with sand for 1 hour, lot B was soaked in concentrated sulfuric acid for 1 hour, lot C was subjected to friction with sand for 1 hour and afterwards soaked in sulfuric acid for an equal period, and lot X was left untreated as a control. Immediately after treatment 250 seeds were planted in each of 2 randomized plats in the open that had been previously fertilized with a 12–6–5 fertilizer. As heretofore, beginning 7 days after planting all plants appearing through the ground were counted as germinated seeds. In table 16 are tabulated the percentages of the seeds of each treatment that germinated at the end of 7, 15, and 30 days.

TABLE 16.—*Effect of sulfuric acid and abrasion with sand on germination of seeds of Hibiscus abelmoschus*

Lot	Treatment [1]	Germination observed at the end of—		
		7 days	15 days	30 days
		Percent	*Percent*	*Percent*
A	Abrasion	6.4	19.6	27.8
B	Soaking in concentrated sulfuric acid	33.6	80.6	83.4
C	Abrasion and soaking in concentrated sulfuric acid	69.0	84.8	87.0
X	Check	4.6	9.6	13.4

[1] 500 seeds in each treatment.

Abrasion with sand followed by soaking in sulfuric acid for 1 hour produced quicker germination of the seeds than either part of this treatment alone. Sixty-nine percent of the seeds in lot C treated in this way germinated within a week and 87 percent within 30 days after treatment, while of the untreated seeds only 4.6 percent germinated in a week and 13.4 percent at the end of 30 days.

Steam distillation of seeds of the musk mallow yielded essential oil.

Several methods of extracting the essential oil, ambrette, from the seeds of the musk mallow were used in small tests carried out as sufficient material became available during the year.

One of these methods employed ether extraction. Fifteen grams of seeds were chopped into small pieces and ground in a mortar until very fine. When extracted with ether for 3 hours in a Soxhlet extractor this material yielded 1 milliliter, or 6.67 percent, of a mixed oil. Another method was steam distillation. For this 150 grams of the finely chopped seeds were distilled for 3 hours, but only 0.3 milliliter, or 0.2 percent, of oil was obtained. However, this oil was freer from fatty acids which might detract from its aroma than was the oil obtained by ether extraction.

Double ether extraction and filtration produced maximum ambrette yield.

A third method involved two extractions with ether followed by filtration. As in the first method, 15 grams of the seeds were chopped and ground in a mortar until very fine. This material was then extracted for 3 hours in 150 milliliters of ether in a Soxhlet extractor and the extract evaporated. The residue was then dried in an oven for 1 hour and extracted a second time. This last residue appeared as a golden-yellow oil with some fatty material, probably a wax, which was filtered out, leaving about 1 milliliter of oil, equal to a yield of approximately 5 percent.

This last is a relatively high yield of this valuable oil, which has been quoted on the New York market at $36 an ounce.

The chemical work on essential oils was begun on August 1, 1937, with the appointment of Noemí García Arrillaga, assistant chemist, who performed the laboratory studies described in the foregoing paragraphs. Carlos R. Saavedra, reporting for duty on September 1, 1937, as assistant agronomist, had charge of the field work connected with aromatic plants here reported.

STUDIES WITH CUT FLOWERS

Puerto Rico has favorable position for winter production of cut flowers.

Under the recent reciprocity treaty between the United States and Canada, the customs tariff on cut flowers imported into the United States is placed at 25 percent ad valorem, reduced from 40 percent. Because of the most-favored-nation clause in treaties with almost all recognized countries, this reduction in rate of import tax will also apply to cut flowers from most other foreign countries.

Cut flowers and florist greens have been produced in Puerto Rico during the winter months without the use of artificial heat which entails heavy costs and overhead. With the possible exception of parts of Florida and California, this island is unique in enjoying such a climatic advantage as well as tariff-free entry to the eastern United States markets. Moreover, as compared with Florida and California, Puerto Rico has the advantage of complete safety from frost; this is not only a safeguard against losses caused by low temperatures but also makes possible the production of a number of additional items of a tropical nature suitable for the florist trade. These considerations have led to studies at the experiment station in the production and shipping of cut flowers and florist greens to the continent.

The production and marketing of winter cut flowers is a specialized industry.

The marketing of winter flowers, a luxury product, is a specialized and organized field. High quality, as well as timeliness, have been shown to be essential. The big turn-over in stock usually has occurred in short and specified intervals during the year; peak sales occur during the Christmas holidays, Easter, and Mother's Day, which have accounted for a large share of the business for the entire year. Fashions and fads have affected the market, but yet the view prevails among florists that cut flowers regardless of shape or color are competitive items one with the other. Florists' opinions are that a customer who has bought orchids at a shop is one less customer who might have bought roses if the orchids had not been available or if they had been of poor quality.

Puerto Rico has the disadvantages of distance from the flower markets on the continent, possibility of damage in transit, and the preference of retailers to deal with nearby established firms. One procedure to minimize these disadvantages and to fit into the specialized trade, is to produce and market items that are not highly competitive.

Tropical flowers have value as novelties.

A number of tropical plants, capable of extensive production in Puerto Rico, possess exotic qualities that make them desirable on the continent either for specialized uses or as novelties; many of these because of their size or specialized environmental requirements are such that they cannot be grown commercially on the continent. Such things as palm and fern leaves grown in the Tropics have the advantage of novelty and cheapness, not obtainable in the North. *Polystichum adiantiforme*, the leather-leaved fern, which is native to the mountain forests of the island, is so durable as a natural green and is so attractive that it is now grown to some extent, but at a considerable disadvantage, in greenhouses in the North.

Congea tomentosa, the Shower of Orchids, offers fine possibilities as dried flowers for winter decorations. This showy climber, which because of its large size is not adapted to greenhouse culture, has long panicles of orchid-colored flowers which, when properly picked, retain most of their attractiveness.

Combretum grandiflorum, native in Upper Guinea and the Congo region of Africa and introduced by the station in 1933, is a large vine which produces its red flowers in numerous close racemes. It blooms at Christmas time and its shades of red and dark green are typical Christmas colors. Its brilliance suggests a place for it in the florist trade as a novelty.

Orchids thrive in western Puerto Rico.

In western Puerto Rico the dependable afternoon rains provide a suitable environment for outdoor culture of commercial orchids. Puerto Rico has advantages for breeding and stock-plant production of Cattleyas and other hothouse orchids. Plant-quarantine measures, which prohibit the transport of soil into the continental United States, do not affect the shipping of most orchids.

The Amazonlily has fine keeping qualities.

Eucharis amazonica, the Amazonlily, as its name implies is a graceful white member of the Amaryllidaceae, beautifully suited for weddings and church decorations. It has shown fine keeping qualities as a cut flower at the experiment station. Its relatively slow growth and propagation and its scattered habit of bloom detract from its value as a greenhouse crop. In Puerto Rico there are possibilities of a large trade in these bulbs if a technique for forcing them to bloom at will can be developed. The local market for fresh-cut flowers of the Amazonlily already exists in a small way and has possibilities of being expanded.

Easter lily (*Lilium longiflorum*) bulbs constitute another staple in the florist trade with a large yearly turn-over. Formerly the supply of these came largely from Japan and Bermuda. Lately Florida and the other Southern States have made gains in supplying the market. Puerto Rico has advantages which might permit obtaining some share in this industry. Lily bulbs from foreign countries pay a customs tariff of $6 per thousand.

The waxflower and foliage of the centipede plant offer unusual promise as a floral novelty.

Phaeomeria speciosa, the waxflower plant, produces a large and compact, resplendent pink flower spike, the most showy features of which are the lustrous, petaloid floral bracts. Introduced by this station from the East Indies years ago, it has excited enthusiastic comment from tourists and visitors more than any other ornamental in the gardens. *Homalocladium platycladum,* the centipede plant, is a large shrub whose flattened, jointed stems are particularly well adapted for use as foliage of coarse texture. The two plants provide a luxuriant combination particularly suitable as large centerpieces, for floor vases, window displays, and lobby decorations. Both plants are too large to be grown in greenhouses and both last well when cut. The combination of waxflowers with foliage of the centipede plant is shown in figure 12.

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FIGURE 12.—The waxflower (*Phacomeria speciosa*) with foliage of the centipede plant (*Homalocladium platycladum*), both cut flower and foliage having fine keeping qualities.

The unusual form of the two plants suggested an experimental refrigerated shipment on June 2 to New York. C. O. Bratley, associate pathologist of the Bureau of Plant Industry, who accompanied the shipment, verified temperatures en route and made observations on the condition of the flowers on arrival at New York.

Four lots of flowers were picked in various stages of maturity on June 1 from a planting on the station grounds, and immediately transported to San Juan, where they were examined and divided into four comparable lots prior to being prepared for shipment. Each lot of flowers was packed in a cardboard box, the stalks being tied to the bottom of the carton to prevent shifting. About a dozen sprays of *Homalocladium platycladum* were placed in each box to protect the flower spikes and to maintain a moist atmosphere about them. The four boxes were placed in different compartments on the boat where different temperatures were maintained. Table 17 gives the location of each lot in the ship and the temperatures at 24-hour intervals taken in boxes of fruit that were adjacent to the boxes of flowers.

TABLE 17.—*Daily temperatures in boat compartments containing experimental shipment of waxflowers en route to New York*

Compartment No. and location on boat	Temperature at 3 p. m.			Compartment No. and location on boat	Temperature at 3 p. m.		
	June 3	June 4	June 5		June 3	June 4	June 5
	°F.	°F.	°F.		°F.	°F.	°F.
2, main deck	85	84	80	1, 'tween decks	62	56	52
5, 'tween decks	62	59	59	4, ice box	51	48	49

The ship docked at New York at 9 a. m. June 6. The flowers were immediately removed from the various compartments and placed in water at room temperature for examination later during the day.

Further study of shipping conditions is needed for waxflower.

Dr. Bratley's examination revealed that much bruising of the petaloid floral bracts had occurred in all lots, and that the bruised areas had become dried and slightly discolored. Black areas on the outer greenish bracts observed at shipping time had increased in size and bore heavy sporulation of an anthracnose fungus. The anthracnose infection constituted an important blemish in all of the four lots shipped. The lots shipped under various degrees of refrigeration were essentially alike on arrival, but the nonrefrigerated lot sent in compartment 2, main deck, was inferior and showed greatest injury from anthracnose. None of the flowers had opened perceptibly. The centipede plant in all lots showed extensive wilting of the leaf edges and tips. In this shipping test the waxflowers were not in a commercially salable condition on arrival in New York City. By trimming away the injured and infected portions, certain flowers from the refrigerated lots might have been made salable.

It was apparent from the experiment that the flowers must be handled carefully at all times, for small bruised areas on the showy petaloid bracts dried and discolored rapidly. If additional test shipments are to be made, it would also be well to use only flowers free from anthracnose. It would be advantageous to handle these flowers with the greatest of care, possibly wrapping them individually in waxed paper and shipping them under refrigeration.

Studies of cut flowers are being carried on by William Pennock, assistant agronomist, and C. L. Horn, associate horticulturist.

BAMBOO PROPAGATION AND UTILIZATION

Station nurseries now contain 2,800 young bamboo clumps.

Both temporary and permanent bamboo plantings have been made at the experiment station during the past year. The temporary plantings, for multiplication and later distribution, were made on level and slightly sloping land, capable of being irrigated if necessary. The plants on such level and gently sloping areas can be dug for distribution without any appreciable loss of loosened soil by erosion. On the other hand, the permanent plantings were made on steep sloping lands which were of little value for any other crop. The bamboo in these permanent plantings serves to utilize previously waste land, minimize soil erosion on the steep hillsides, and to produce culms for shop use.

At the close of the fiscal year there were 2,838 clumps of young industrial bamboos growing in 12¼ acres of propagating fields; each clump will divide into at least five plants when ready for distribution. The clumps in the nurseries are listed by species in table 18.

TABLE 18.—*Plantings of bamboo at the experiment station, June 30, 1938*

Nature of plantings	Area	*Bambusa tulda*	*B. tulda* type 2	*B. vulgaris* var. *auria striata*	*B. ventricosa*	*B. disticha*	*B. arundinacea*	*B. balcooa*	*B. tuldoides*
	Acres	*Clumps*	*Clumps*	*Clumps*	*Clumps*	*Clumps*	*Clumps*	*Clumps*	*Clumps*
Nurseries	12¼	495	4	108	10	72	65	142	231
Permanent	17½	961	128	1	14	10	615	256	202
Total	29¾	1,456	132	109	24	82	680	398	433

Nature of plantings	*B. longispiculata*	*Dendrocalamus strictus*	*D. membranaceus*	*D. latiflorus*	*D. giganteus*	*Phyllostachys* sp.	*Gigantochloa* sp.	Miscellaneous	Total
	Clumps	*Clumps*	*Clumps*	*Clumps*	*Clumps*	*Clumps*	*Clumps*	*Clumps*	*Clumps*
Nurseries	506	586	162	89	33	218	20	97	2,838
Permanent	70	406			2		2	20	2,687
Total	576	992	162	89	35	218	22	117	5,525

Propagation by layering has been successful.

When it is considered that the foregoing numbers of bamboo plants originated from 5 parent clumps of *Bambusa tulda*, 26 clumps of *Dendrocalamus strictus*, 1 clump of *B. arundinacea*, and shipments of potted seedlings from the Bureau of Plant Industry in Washington, it can be seen that the layering method of propagating has been successful. This method of layering is described in the annual report for 1936, but since that time the method has been improved from time to time. Figure 13 shows the principal steps in layering bamboo. It can be seen that whole culms with the roots adhering were excavated and as much soil balled to the roots as possible. The side branches were cut off, leaving the axillary buds and a few mature leaves. The culm was then planted horizontally in a furrow; since the roots at the base of the culm continued to function, germination of the axillary buds took place and small plants formed at a large proportion of the

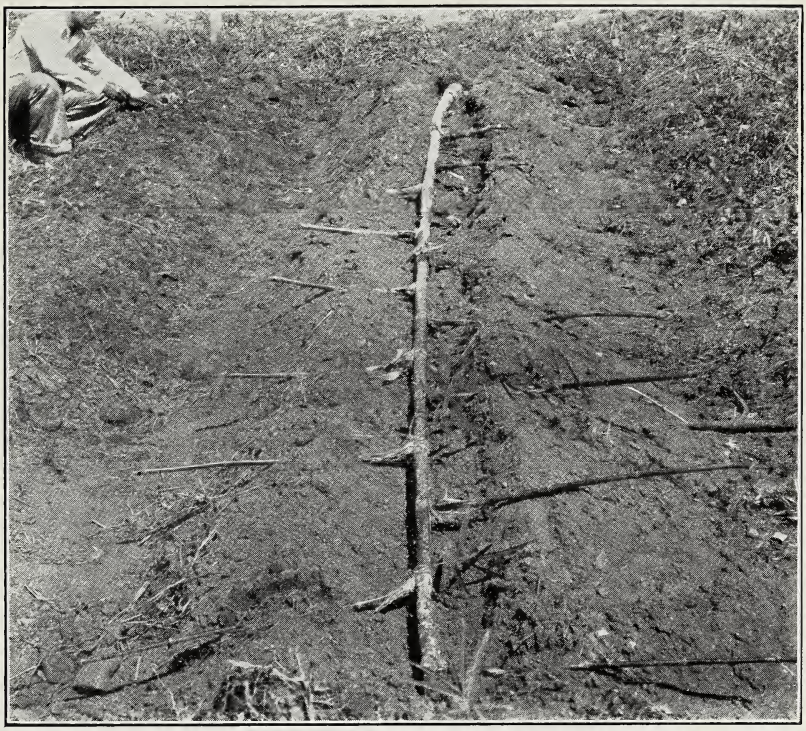

FIGURE 13.—A bamboo culm with roots attached and lateral branches cut back placed in furrow ready for fertilizer application prior to covering with soil.

nodes of the culm. Some species propagate much more readily than others by this method. The absorption of nutrients by the horizontally planted culms was aided by the application of such fertilizers as ammonium sulfate to the roots and nodes before the culm was covered.

Permanent bamboo plantings now occupy 17 acres at the experiment station.

In order that wood from insect-resistant industrial bamboos may be available for utilization and mass-production studies in the shop, considerable permanent plantings have been made during the year. The extent of these plantings is also shown in table 18. There are 2,687 clumps of industrial bamboos, in various degrees of approaching maturity, covering 17 acres.

Bamboo plantings require 5 to 6 years before culms can be harvested.

It is a commonly expressed opinion that bamboo is a quick-growing crop that can be harvested within a year or so after planting. Experience in Puerto Rico has shown that little or no bamboo can be harvested in less than 4 years, and it is more conservative to state that 6 years of growth are required before bamboo can be harvested with the best results. When bamboo is first planted, the first flush of growth usually consists of short culms of small diameter. The second flush of growth is of larger diameter and greater length, and with each new flush of growth the new culms are of increased size both longi-

tudinally and diametrically. Apparently the clumps store up food reserves with age, thus enabling successive flushes of growth to produce larger and more vigorous culms.

Publications from India indicate that 5 or 6 years are necessary for the maturity of culms of *Dendrocalamus strictus*. The experience to date at the experiment station indicates that this is a conservative policy to be followed. Three or four years are necessary for the bamboo clumps to develop culms of maximum diameter and length,

FIGURE 14.—A 2-year-old clump of the bamboo *Gigantochloa aspera*, showing the slender stalks of the first growth and the increased diameter of the culms with each new flush of growth.

and thereafter such culms must mature in the clump for 1 or 2 years before being harvested.

Once the clumps have reached the stage where large-size culms are being produced, then such culms after maturing in the clump for 1 or 2 years may be harvested annually. Figure 14 shows the culms of different diameters in successive flushes of growth.

Scale insects are severe on several bamboo species.

During the year, two species of scale insects (*Asterolecanium miliaris* (Bdv.) and *A. bambusae* (Bdv.)) caused damage to bamboo. There were great differences in susceptibility to these insects in different species of bamboo. One strain sent to the station as *Bambusa tulda* is particularly susceptible as is also *B. vulgaris*. *Dendrocalamus strictus* is slightly less susceptible, but, nevertheless, is frequently heavily infested. Such hardwood species as *D. giganteus*, *Gigantochloa aspera*, *B. tulda*, and *B. arundinacea* are occasionally attacked but not severely. These two scale insects in typical infestations on *D. strictus* are shown in figure 15.

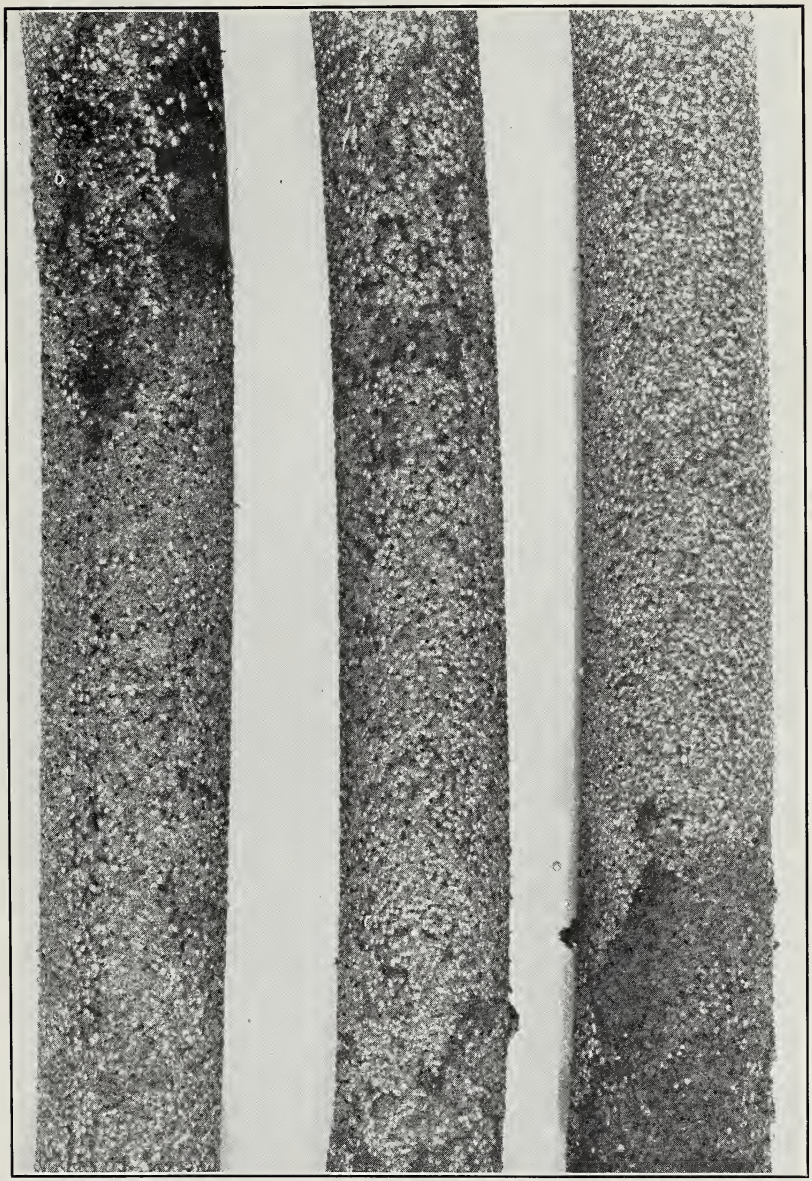

FIGURE 15.—A typical heavy infestation of the culms of the solid bamboo (*Dendrocalamus strictus*) by the scale insects *Asterolecanium miliaris* and *A. bambusae*.

Bamboo-utilization studies are awaiting production of mature culms of new bamboo species.

Studies of bamboo utilization have not been emphasized during the year because of insufficient quantities of mature culms of the industrial bamboo species. A new use for bamboo at the experiment station which, however, has long been in practice in the East Indies, has

been the conduction of irrigation water through bamboo culms. This is shown in figure 16. A desk made of culms of *B. tulda* is also shown in figure 17. An additional shelter with a bamboo roof was con-

FIGURE 16.—Culms of the common bamboo, *Bambusa vulgaris*, being used for conduits to conserve irrigation water.

FIGURE 17.—A desk, chair, wastebasket, flower vase, smoking stand, cigar humidor, desk lamp, and other desk accessories, constructed of bamboo in the station experimental shop for bamboo utilization. The picture in the bamboo frame is that of Frank D. Gardner, the first director of the Puerto Rico Experiment Station.

structed for dairy animals, making an unusually cheap but attractive shed and serving the purpose in a wholly satisfactory way.

The bamboo studies during the year have been carried on by Armando Arroyo, scientific aide, and Atherton Lee, director.

INVESTIGATIONS OF INSECTICIDAL PLANTS

Many species have been eliminated as potential insecticidal plants.

The work with insecticidal plants was continued along much the same lines as during the past 2 years. During the present fiscal year, however, the major emphasis of the work was definitely shifted to more intensified investigations of those species of *Derris* and *Lonchocarpus* which have shown possibilities of commercial production.

A total of 343 introductions of fish-poison plants has been accessioned to date, some of which were dead upon receipt or did not survive local growing conditions. Of this total, 122 introductions have been completely harvested, save for the fruits, and 29 other introductions have been partly harvested. At the end of the fiscal year there remained 87 introductions surviving in the fields from which no harvest had been made, 54 of which were propagated to secure sufficient material for further investigation.

Of the 597 plant fractions prepared to date for toxicological studies, 268 were shipped to the Bureau of Plant Industry during the fiscal year. By far the greater number of these plant fractions contained no rotenone. Investigations later conducted by the Bureau of Entomology and Plant Quarantine showed that plant fractions containing little or no rotenone were so ineffective as insecticides that they can be considered of no commercial value for this purpose. The Durham test for rotenone and certain of its allied compounds was applied to 157 plant fractions during the year. Other than previously reported, no additional species was found positive to this test.

Duplicate herbarium specimens of 190 introductions have been prepared for identification by collaborators in the Department of Agriculture.

Seedlings of Derris elliptica showed wide variations in vigor.

During the spring of 1937, exploratory studies in the pollination of several varieties of *Derris elliptica* resulted in the production of seed which, when planted in October and November, produced 41 seedlings. Seedlings resulting from controlled self-pollination of two unidentified varieties secured from St. Croix were found to be uniformly vigorous. When these varieties were crossed with the variety Changi No. 3, the vigor of the seedlings was noticeably reduced, one seedling of this cross having died.

Preliminary work involving reciprocal crosses and open-pollination of the varieties Changi No. 3 and Sarawak Creeping, yielded 29 seedlings.

Roots from a plant of Lonchocarpus analyzed 14 percent rotenone.

Of 10 plants that were received on April 26, 1932, as *Lonchocarpus nicou*, P. I. No. 97923, two became established. By the spring of 1937, these plants, one of which is shown in figure 18, had attained sufficient size to allow the removal of roots for testing without seriously injuring the plants. Duplicate analyses of roots, made by the Division of Drug and Related Plants of the Bureau of Plant Industry,

showed that the principal roots of these plants contained unusually high concentrations of rotenone and total chloroform extractives. In one case the concentrations of these constituents were the highest that have been reported. Because of their high rotenone content, the erect growth habit of the stems, the relatively large leaves, and the tapering form and pronounced tendency of the roots to grow down into the soil rather than laterally, these plants were judged to be representatives of the species recently described by Krukoff as *L. utilis*.

FIGURE 18.—Plant of *Lonchocarpus utilis* which yielded high concentrations of rotenone.

In addition to the above-mentioned plants of high rotenone content another plant, introduced by a private planter, was found to contain 14.02 percent of rotenone.

High-rotenone scions were successfully budded onto low-rotenone stocks of Lonchocarpus.

Budding offered the most efficient method for rapidly increasing the supply of clonal cutting material of individual plants of superior rotenone content. Under favorable environmental conditions, buds from the plant of high rotenone content were successfully transferred to well-established and vigorous stock plants, most of which were doubtless of much lower rotenone content. Transfer of buds from the high-content plant was made in May and June. In the first trial, 10 of 13 buds became established and produced new shoots under the favorable weather conditions that prevailed during the 2 weeks after budding. In a second trial only 10 of 42 buds produced new shoots, largely because of a series of dry windy days which began shortly after the grafts were made. In another test in which buds of a 14.02-percent plant were used, 17 buds out of 39 produced new shoots. In general, it was observed that budding could be done more successfully during cool, cloudy weather than during protracted periods of sunshine, drought, and wind. The rate of growth of the new shoots

was found to be roughly proportional to the size of the plant onto which the buds had been placed. In these preliminary trials, no correlation was observable between age of buds and success or failure of grafts. Buds taken from stems more than an inch in diameter were as apt to unite with the stock plants as those taken from near stem tips.

Most of the plants chosen for stocks closely resembled the plants from which buds were taken. However, in four cases buds from the higher rotenone-yielding plants just mentioned were successfully grafted onto an unidentified species of *Lonchocarpus* having a bushlike habit of growth with many of the stem tips becoming vinelike.

Propagating material of high-rotenone plants was completely utilized.

In order to utilize to the fullest extent the propagating material of the few plants of known high rotenone content, all of the buds were not removed from the stems for scion material. Those allowed to remain were distributed to provide two buds for each section of the stem to be made into a cutting. The gaps left in the bark by the removal of buds were immediately covered with paraffin heated to just above the melting point. By preventing desiccation and death of the cambium this coating permitted regeneration of bark over the surface of the wound and thus protected the wood from invasion by decay organisms. Complete regeneration of bark followed this treatment, as illustrated in figure 19. The rooting of cuttings made from the stems treated in this manner was not noticeably impaired.

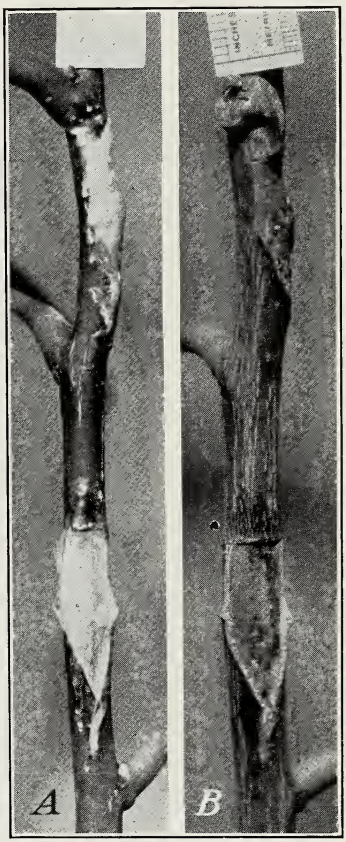

FIGURE 19.—Paraffin as a covering for wounds on *Lonchocarpus* stem where buds had been removed: *A*, Photographed shortly after buds were removed and paraffin was applied to the wounds; *B*, the same stem as *A* photographed 9 weeks later showing complete regeneration of bark over the surface of the wounds.

Attempts to graft dissimilar species of Lonchocarpus were unsuccessful.

When the first attempts were being made to increase the supply of cutting material of the high-rotenone plants of *Lonchocarpus* by budding, only a few well-established plants of closely related species were available as stocks. As an ample number of vigorous young trees of several more-distantly related species of *Lonchocarpus* were available, a test was conducted in which these were used as stock plants. One variety of *Derris elliptica* of low rotenone content but of high vegetative vigor was also included in this test. Bud material was secured from the two plants of *L. utilis* surviving from the shipment of April 26, 1932, discussed in an earlier section of this report.

Even though the budding operations were done in February, the middle of the dry season for Mayaguez, the bark of the stock plants loosened readily from the wood and showed sufficient cambial activity for graft union to occur.

Although the buds used in this test lived for several days, none gave evidence of beginning to unite with the cambium of the stock plants. It would appear that budding operations to increase the supply of cutting material of superior plants of *Lonchocarpus* should be confined to the use of stock plants of closely related species.

Stored rotenone was not reutilized in the metabolism of Tephrosia toxicaria and Derris elliptica.

In order to plan basically sound argonomic experiments with rotenone-producing plants, it is of primary interest to know whether rotenone and its allied compounds once formed can be reutilized in the metabolism of the plants producing them. If it were possible to reutilize rotenone, then the cultural practices which might increase its concentration in the plant would probably coincide for the most part with those widely used to improve crops whose value depends largely upon their carbohydrate content. On the contrary, sh uld rotenone prove not to be a source of materials for the building of new tissues and respiration, the field practices which might increase the concentration of rotenone would necessarily be of a fundamentally different kind.

The simplest approach to a solution of this problem was considered to be an experiment in food exhaustion. To test the possibilities of this approach, well-established plants of *Derris elliptica* and *Tephrosia toxicaria* were cut back to stumps about 6 inches long, and newly expanded leaves removed from them at regular periods of 4 days until a few plants had died. The roots of the dead plants were found to be practically free from starch but had apparently undergone no decrease in the amount of rotenone present as shown by the Durham test.

The defoliated plants had only a few fine roots at the time of harvest in contrast to the control plants which had produced fine roots in abundance; because of this it was necessary to harvest a greater number of the defoliated plants than of the controls in order to obtain a sample of fine roots of sufficient weight for chemical analysis. Thirty-five defoliated plants and sixteen control plants of *Tephrosia toxicaria* were harvested; for *Derris elliptica* the numbers were 20 and 10, respectively.

It was observed that the size and number of leaves became noticeably reduced for a short period prior to death of the plants. Living roots of plants tested at this stage of food exhaustion were found to contain little or no starch. When the plants reached this condition they were dug up for chemical analysis. Because the rotenone content of roots has been found to vary with diameter, the roots were sorted into five size groups. Weights were taken of each size group at the time of harvest and after drying at 80° C. for 4 hours. The volume of roots in each size group was determined by water displacement and diameter and length measurements of the individual roots. This routine of preparation was also followed for control plants.

Even though chemical analyses have not been reported for these tests on food exhaustion, the evidence otherwise definitely points to the fact that the substances positive to the Durham test cannot be

considered plant foods that can be reutilized in plant growth in the same sense that carbohydrates are reutilized. This being true, the field practices which might be employed to increase rotenone content logically might differ from those practices tending to increase the carbohydrates in crop plants.

Investigations of insecticidal plants have been conducted by Rufus H. Moore, associate plant physiologist.

VEGETABLE CROP INVESTIGATIONS

SWEET CORN BREEDING AND SEED DISTRIBUTION

Sweet corn varieties that grow in continental United States are failures in Puerto Rico.

Beginning in 1901 and continuing intermittently until 1936, repeated attempts were made by the experiment station to grow continental American varieties of sweet corn. Almost all of these tests have resulted in failure; in many instances not a single ear was obtained.

At least three factors appear to be involved in this lack of adaptability of continental sweet corn to Puerto Rican conditions. The continental varieties are susceptible to yellow stripe, a virus disease, and to a *Helminthosporium* leaf spot, both of which are prevalent. Aside from these diseases, continental sweet corn appears to be adversely affected by the shorter day lengths of the Tropics as compared with the longer day lengths of the continent during the season of the year when sweet corn is grown there.

USDA–34, a variety of native sweet corn, is well-adapted to Puerto Rico.

In 1934, as a culmination of 16 years' breeding and selection work, the experiment station made available to farmers a variety of native sweet corn, USDA–34, that was well adapted to Puerto Rican conditions. A short history of the origin and breeding of this variety was printed in the annual report for 1935. USDA–34 sweet corn is more resistant to yellow stripe and *Helminthosporium* leaf spot than are the continental varieties, and under favorable conditions of soil moisture and fertility it makes a vigorous growth, bearing medium- to large-sized ears with deep cream-colored kernels of unusually good flavor.

USDA–34 sweet corn is not uniform in all characters.

USDA–34 sweet corn was not altogether uniform in certain characters. There was considerable variation in color of stalks, husks, cobs, and kernels, in size and shape of kernel, and in extent of pseudo-starchiness. Attempts have been made to reduce the proportion of undesirable types and maintain them at a minimum in the seed stock for general distribution by careful selection of both seed plants in the field and seed ears following harvest. In the meantime a breeding program was started in an effort to eliminate as much of the existing variability as possible.

The program called for inbreeding a large number of lines for at least three generations, discarding undesirable types and then recombining a number of the most promising inbred lines in an effort to synthesize a new superior variety. To date more than 2,000 plants resulting from bulk seed from rigidly selected open-pollinated ears have been selfed. The S_1 generation of the 200 most desirable resulting ears

has been grown and the plants selfed. Seed from 325 S_2 ears representing 85 of the most desirable inbred lines was planted and more than 10,000 resulting plants selfed.

Segregation for resistance to rust appeared in S_2 generation.

The segregation obtained in the S_2 generation indicated that a large number of genotypes was present in the original seed. The uniformity obtained for certain characters in the S_2 generation has been gratifying. Of special interest has been the segregation in

FIGURE 20.—USDA–34 sweet corn plants, S_2 generation, 75 days from planting, showing difference in susceptibility to corn rust (*Puccinia sorghi* Schw.): *A*, Typical of plants in certain selections that were susceptible to rust; *B*, typical of plants from selections resistant to rust.

several lines for resistance to corn rust (*Puccinia sorghi* Schw.). The foliage of all of the plants developing from one selection in each of two of the lines was almost completely destroyed by the rust by the time the kernels had reached the roasting-ear stage. In figure 20 are shown two corn plants 75 days from planting; *A* was severely infected with rust and was typical of plants of the rust-susceptible S_2 selections mentioned above; *B* was typical of the plants of resistant S_2 selections growing in rows adjacent to the severely infected selections.

SWEET CORN SPACING STUDIES

A series of agronomic tests with USDA–34 sweet corn has been conducted.

Since the first general distribution of USDA–34 sweet corn seed in 1934 a series of agronomic tests has been conducted to determine

something of the fertilizer requirements and best spacing practices for this crop on different soil types. An account of the results of some of the first sweet corn agronomic experiments can be found in the annual report for 1936. The results of several other experiments completed since then are presented in the present report. The results of one of the 1937 experiments were published in the Journal of the American Society of Agronomy, and are reviewed here.[3]

A sweet corn spacing experiment was conducted in summer of 1936.

A sweet corn spacing experiment, conducted on one of the level, heavy clay lowland fields of the experiment station, was designed to determine the relation between soil area per plant and yields of corn ears and forage. With one plant per hill, distances between rows and between hills were varied to give areas per plant ranging by ½-square-foot intervals from 2 square feet to 4.5 square feet. The 6 treatments were replicated 25 times each, and in order to provide for statistical analysis of the data, a randomized block system of laying out the field was used. The plats measured 36 by 31 feet, giving approximately 39 plats per acre. To insure adequate drainage and aeration the corn was planted on ridges. The seed was planted May 18 to 23 and the crop harvested August 18 to 21, 1936, 92 days from planting and approximately 15 days after the ears had attained their highest eating quality.

At harvest, records were made of the number of plants, the number and weight of all ears, and weight of forage in each plat. After the ears had been allowed to become thoroughly dry under shelter, they were classified into marketable and nonmarketable and the number and weight in each group were recorded by plats.

Statistical analyses of yields showed treatment differences to be highly significant.

The yield data were analyzed statistically by the analysis of variance method of Fisher. The analysis for dry weight of all ears and for the number and green weight of marketable ears showed that treatment differences as compared with differences due to experimental error were highly significant. The yields on an acre basis are summarized briefly in table 19.

TABLE 19.—*Comparative yields obtained with various soil areas per plant in sweet corn spacing experiment, Mayaguez, P. R., harvested August 1936*

Lot	Distance between—		Soil area per plant at time of seeding	Stand of plants at harvest	Soil area per plant at time of harvest	Marketable ears per acre [1]	Average air-dry weight per marketable ear	Proportion of total number of ears marketable	Total ears per acre	Air-dry weight of all ears per acre	Forage per acre at harvest time
	Rows	Hills									
	Inches	*Inches*	*Square feet*	*Percent*	*Square feet*	*Number*	*Ounces*	*Percent*	*Number*	*Pounds*	*Pounds*
A	24	12.0	2.0	71.7	2.79	5,734	3.827	40.1	14,294	2,272	6,191
B	24	15.0	2.5	75.8	3.30	5,005	3.893	39.0	12,839	2,027	5,470
C	36	12.0	3.0	88.1	3.41	5,774	4.144	45.1	12,791	2,269	5,887
D	36	14.0	3.5	88.5	3.95	4,700	4.066	42.3	11,124	1,857	4,972
E	48	12.0	4.0	76.3	5.24	3,560	4.061	41.6	8,560	1,411	3,602
F	48	13.5	4.5	75.7	5.94	3,441	4.069	42.6	8,079	1,347	3,765

[1] Marketable ears had at least 5 inches of cob well filled with well-developed kernels free from damage of any kind.

[3] WATSON, ALFRED N., and DAVIS, ROBERT L. THE STATISTICAL ANALYSIS OF A SPACING EXPERIMENT WITH SWEET CORN. Jour. Amer. Soc. Agron. 30: 10–17. 1938.

Closest spacing resulted in highest quantity production.

Inasmuch as three different row widths were used in addition to different distances between hills to secure the desired land areas per plant, and since the 48-inch row width was obtained by planting every other ridge with the ridges spaced 24 inches apart, close comparisons among the treatments cannot logically be made except between lots A and B, C and D, and E and F. Nevertheless, for those yield factors indicating quantity production, such as number and weight of all ears and weight of forage, the highest average yields were obtained with the closest spacing.

Largest yield of marketable ears was obtained with average soil area of 3.41 square feet per plant.

For the yield criteria representing quality production, the best results were obtained with the spacing that gave an average soil area at harvest time of 3.41 square feet per plant; such criteria were number of marketable ears, average weight per marketable ear, and proportion of all ears marketable. There was an appreciable decrease in average weight of marketable ears with less average area per plant.

Lodging was accentuated when corn was planted on narrow ridges.

In addition to the data shown in table 19, some interesting and valuable information was obtained on the effect of the spacing treatments on percent of plants lodging and on diameter of stalks. These relationships are shown in table 20. When the corn was planted on the narrow ridges resulting from the 24-inch row spacing, as in lots A, B, E, and F, the proportion of plants lodging was from 26 to 120 percent greater than when the corn was planted on the wider ridges of the 36-inch row spacing.

TABLE 20.—*Differences in lodging and diameter of stalks resulting from various spacings with USDA–34 sweet corn, Mayaguez, P. R., harvested August 1936*

Lot	Average soil area per plant at time of harvest	Distance between ridges	Lodging	Average diameter of lowest internode of stalk [1]	Lot	Average soil area per plant at time of harvest	Distance between ridges	Lodging	Average diameter of lowest internode of stalk [1]
	Square feet	*Inches*	*Percent*	*Centimeters*		*Square feet*	*Inches*	*Percent*	*Centimeters*
A	2.79	24	16.7	1.95	D	3.95	36	8.2	2.18
B	3.30	24	18.0	2.01	E	5.24	[2] 24	15.0	2.18
C	3.41	36	11.6	2.13	F	5.94	[2] 24	14.6	2.16

[1] Based on counts of 10 stalks in each of 20 plats of each treatment.
[2] Corn planted on every other ridge.

Diameter of stalks decreased as soil areas per plant were decreased below 3.95 square feet.

With an average soil area per plant of from 5.94 to 3.95 square feet there was practically no difference in the average diameter of the stalks at the lowest internode; but below 3.95 square feet per plant the average diameter of the stalks decreased consistently until with an area of 2.79 square feet per plant it was approximately 10 percent less than when the area per plant was 3.95 square feet or greater.

This spacing experiment was planned and conducted by Atherton Lee, A. N. Watson, R. L. Davis, and Jorge Rodriguez Iñigo. The ears were graded by Wallace K. Bailey.

A second sweet corn spacing experiment was planted in fall of 1936.

Another sweet corn spacing experiment was planted in the same field November 18, 1936. Four different soil areas per plant were used. Each average area per plant was obtained by 4 different combinations of row and hill spacings. Each of the 16 different row and hill spacings was replicated 8 times with each plat approximately one forty-third of an acre in area. Because the dry season of the year was approaching, the seed was planted in shallow furrows rather than on ridges as in the previous experiment.

Planting was severely damaged by fall armyworm.

Plant counts at harvest time showed that as a result of a severe and well-distributed infestation of larvae of the fall armyworm (*Laphygma frugiperda* (A. and S.)), soon after the plants came up, the average stand for the whole experiment was approximately only 34 percent. In view of this fact the original design of the experiment was abandoned.

Nevertheless, the ears of one-half of the 142 available plats were harvested green, and those of the remaining half were allowed to mature and were harvested for seed and dry-weight records. Individual plat records were obtained at both harvests for the number and weight of all ears, number and weight of marketable ears, and weight of forage. Utilizing the stand counts, the yield data for the individual plats were arranged in the order of the average soil area per plant. Table 21 shows certain of the green-corn yield values after the individual plats have been classified according to the soil area per plant.

TABLE 21.—*Yields obtained with various soil areas per plant in spacing experiment with USDA–34 sweet corn, Mayaguez, P. R., planted November 1936 and harvested February 1937* [1]

Area per plant at harvest (square feet)	Plats	All ears per acre		Marketable ears per acre	Average weight per marketable ear	Weight of forage per acre
	Number	*Number*	*Pounds*	*Number*	*Ounces*	*Pounds*
1.25–1.74	3	24,226	6,619	2,636	8.13	13,049
1.75–2.24	4	20,060	6,936	5,434	8.38	11,430
2.25–2.74	5	16,869	6,179	5,358	8.70	9,731
2.75–3.24	8	13,022	5,768	6,497	8.93	9,323
3.25–3.74	6	12,459	5,401	6,266	8.95	7,649
3.75–4.24	6	11,156	4,552	5,164	9.06	7,173
4.25–4.74	6	10,875	4,379	5,178	9.07	6,621
4.75–5.24	5	10,647	4,425	5,203	9.04	6,654
5.25–5.74	4	9,338	4,327	5,277	9.69	6,226
5.75–6.24	4	8,265	3,521	3,219	8.83	5,250
6.25–6.74	6	7,778	3,731	4,256	9.99	5,010

[1] Harvested at roasting-ear stage.

Results of second spacing experiment substantiated results of first experiment.

Although as a result of the depredations of the fall armyworm the plants were not uniformly distributed in many of the plats, and although the yield values were based on results from a comparatively small number of plats, it will be noted from table 21 that with respect to both quantity and quality production, the yields obtained with the

different average soil areas per plant substantiated in a large measure the results obtained in the preceding spacing experiment. In general, total quantity production continued to increase as the average soil area per plant decreased, whereas quality production tended to reach a maximum between 2.75 and 3.24 square feet per plant and then decreased sharply with soil areas less than this amount. The results obtained for the one-half of the plats on which the ears were allowed to mature substantiated closely those obtained for the corn harvested at the roasting-ear stage.

This second spacing experiment was planned by A. N. Watson and carried out by A. N. Watson, Wallace K. Bailey, and Jorge Rodriguez Iñigo.

Three square feet of soil area per plant at planting time was adopted as standard practice.

As a result of the sweet corn spacing experiments the practice of using row widths and hill spacings that will give a soil area per plant of 3 square feet, making the rows for USDA–34 sweet corn 3 feet apart with the hills 12 inches apart in the row, has been adopted as a standard practice at the experiment station. Allowing for some unavoidable reduction in stand, this spacing has been found to give at harvest time an average soil area per plant of 3.25 to 3.50 square feet, an area range that was found in the spacing experiments to give a high yield of marketable ears without unduly sacrificing ear size. It was felt that such a spacing practice could be expected to give excellent results with USDA–34 sweet corn in other sections of the island where the soils are moderately fertile, moderate applications of commercial fertilizer are made, and an abundance of soil moisture is assured. On poorer soils that are not heavily fertilized and in sections where an abundance of soil moisture is not assured, a spacing practice allowing for a larger average soil area per plant is recommended for the production of the maximum quantity of marketable ears of acceptable size.

SWEET CORN FERTILIZER STUDIES

Nitrogen was an important limiting factor in sweet corn production.

During 1937 a multiple-objective fertilizer experiment was conducted with USDA–34 sweet corn on the heavy clay lowland soil of the experiment station. This experiment tested the effectiveness of varying quantities of nitrogen, phosphorus, and potassium and of each of these constituents with constant quantities of the other two. The nitrogen was derived from ammonium sulfate, the phosphorus from tricalcium phosphate, and the potassium from sulfate of potash.

Under the conditions of the experiment, nitrogen was found to be a highly important limiting factor in sweet corn production, the importance of phosphorus was not conclusively demonstrated, and potassium was definitely not a limiting factor.

Using 160 pounds of nitrogen per acre increased yield of longer marketable ears more than 31 times.

In the nitrogen-quantity test portion of the experiment the highest yields were obtained with the maximum nitrogen application of 160 pounds per acre. With increasing quantities of nitrogen in the fertilizer mixture highly significant increases were obtained in number and weight of all ears, all marketable ears less than 7 inches long, and

all marketable ears 7 inches long or longer, and in weight of forage. With 160 pounds of nitrogen in the fertilizer mixture an average production of 9,988 marketable ears was obtained, approximately eight times that of the no-nitrogen treatment; the yield of marketable ears 7 inches long or longer was increased 3,138 percent. Increasing quantities of nitrogen increased the proportion of ears marketable, the average weight per marketable ear, the average stalk size, the number of marketable ears per stalk, and greatly increased the efficiency of the plants in the production of marketable ears per unit of stalk weight.

The results of this experiment have been prepared for publication in greater detail in a technical journal. The tricalcium phosphate used in this experiment was furnished by the Tennessee Valley Authority.

Earworms are chief limiting factor in sweet corn production.

At present the most serious handicap to the production of sweet corn is the prevalence of earworms, the three most important of which are the corn earworm (*Heliothis armigera* Hbn.), the fall armyworm (*Laphygma frugiperda* (A. and S.)), and the corn-silk fly (*Euxesta stigmatias* Loew). By far the most prevalent of these is the corn-silk fly.

Results of experiments during the past year showed that clipping off the silks and ends of the husks soon after the silks begin to wilt noticeably and covering the ears with paper or glycine bags effected large and consistent reductions in the proportion of ears infested with corn-silk fly larvae; by this method the corn-silk fly infestation has been reduced from 99.6 percent to 18.5 percent. The reductions were not so large nor so consistent for the corn earworm and the fall armyworm.

SWEET CORN SEED TREATMENT STUDIES

Arsenate of lead treatment of sweet corn seed has been used to control rodents.

For many years this experiment station has been treating sweet corn seed with arsenate of lead at planting time to prevent rats and mice from digging up the seed before and during germination and thus lessening the stand of plants obtained. Numerous field observations had indicated that this treatment was effective in minimizing field damage of freshly planted seed by rodents; but at times the stand of plants resulting from such treated seed was disappointing, and furthermore, in some instances the plants appeared stunted for a short time after they first came up.

One method of treatment consisted of stirring the seed for planting in an approximately equal volume of water for several minutes, draining off the excess water, and then rolling the moist seed in dry, powdered arsenate of lead until every kernel became coated with the poison dust. Since much of the success of sweet corn agronomic experiments depended upon the stand of plants obtained, it had been the practice at the station to plant from five to seven seeds per hill. Thus there was a considerable quantity of arsenate of lead in each hill in direct contact with the seed during and following germination.

Sweet corn plantings were made to determine effect of arsenate of lead on stand.

Since some arsenical compounds have been shown to be toxic to higher plants, except when present in extremely small quantities, it seemed advisable that experiments be conducted with sweet corn to determine, under various soil and other environmental conditions, what effect arsenate of lead seed treatment might have on the stand of plants and their early growth. One test planting was made on Las Mesas, another in Jensen field, and four others in River field, each of the latter four on a different date and in a different part of the field.

Each planting consisted of three treatments; untreated seed was tested against seed treated with arsenate of lead by the method just described and seed treated with a proprietary organic mercury dust. Five seed were planted per hill on ridges with the rows 30 inches apart and the hills 18 inches and 24 inches apart in the row, depending upon the field involved. In order that all treatments might be as equally exposed as possible to all soil conditions within each of the six plantings, single-hill alternations of the treatments were used. The planting was carried out in such a way that an equal portion of the seed for each treatment was planted by each of three laborers. The treatments were replicated from a minimum of 96 times in the fourth River field experiment to a maximum of 190 times in the third River field experiment.

Arsenate of lead seed treatment consistently reduced the stand of plants.

Stand counts on an individual-hill basis were made 10 to 14 days after planting. A statistical analysis of the data from each planting by means of analysis of variance showed that in all six plantings the variance due to treatments was highly significant when compared with error.

The summarized results of the seed treatments as measured by stand counts are shown for all six plantings in table 22. Although the results varied from planting to planting, the seed treated with arsenate of lead consistently gave a smaller number of plants than did the untreated seed and that treated with the organic mercury dust. In every one of the six plantings this reduced stand from the arsenate of lead treated seed was so marked that the odds were much greater than 99 to 1 that it was not brought about by chance alone. The average reduction in stand due to treating the seed with arsenate of lead amounted to more than 72 percent.

TABLE 22.—*Effect of different methods of seed treatment on stand of USDA–34 sweet corn plants*

Experimental plantings	Replications	Seed planted per treatment	Stand resulting from—		
			Seed treated with arsenate of lead	Untreated seed	Seed treated with organic mercury dust
	Number	*Number*	*Percent*	*Percent*	*Percent*
Jensen field	153	765	32.2	56.2	[1] 62.0
Las Mesas	120	600	57.5	78.2	[1] 83.0
River field No. 1	112	560	48.0	72.7	75.4
River field No. 2	124	620	9.5	44.7	[1] 51.0
River field No. 3	190	950	33.5	63.4	61.9
River field No. 4	96	480	39.2	64.2	57.5
All experiments	795	3,975	35.8	62.7	64.8

[1] Superior to stand from untreated seed by odds greater than 19 to 1.

Organic mercury dust seed treatment improved stand of sweet corn in four experiments.

The differences between the stands obtained with the untreated seed and those from the seed treated with the proprietary organic mercury dust were not so striking nor consistent as the differences between these two groups and the arsenate of lead group. In the first four experimental plantings more nearly complete stands were obtained from the use of seed treated with organic mercury dust than from untreated seed, and in three of the four plantings the odds were greater than 19 to 1 that the superiority of the mercury dust treatment was not the result of chance alone. In the last two plantings better results were obtained with untreated seed than with that treated with organic mercury dust, but the differences were not large enough to give odds as great as 19 to 1 that they were due to some factor other than chance; hence the observed differences were considered not significant.

Arsenate of lead seed treatment resulted in a large proportion of missing hills.

In table 23 the hills in the six plantings as a whole are classified according to the number of plants they contained. The data show that the superiority of the untreated seed and the seed treated with the organic mercury dust over the seed treated with arsenate of lead was the result of a smaller proportion of hills that had no plants or only one and two plants each, and a larger proportion of hills with three, four, and five plants each. Only 28.4 percent of the hills planted with seed treated with arsenate of lead had as many as three plants per hill; of the hills planted with untreated seed and those treated with organic mercury dust more than 73 percent had three plants or more. Conversely, more than 71 percent of the hills planted with seed treated with arsenate of lead had no more than two plants per hill, whereas with the other two treatments less than 27 percent of the hills had no more than two plants each.

TABLE 23.—*Effect of different methods of sweet corn seed treatment on number of plants per hill*

Seed treatment	Total hills	Hills with—					
		0 plants	1 plant	2 plants	3 plants	4 plants	5 plants
	Number	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Arsenate of lead	784	16.2	26.0	29.3	18.6	8.0	1.8
Untreated	784	1.9	7.0	18.0	30.9	28.6	13.6
Organic mercury dust	784	2.7	8.4	14.3	27.2	27.9	19.5

The data in table 23 for the untreated seed and the seed treated with arsenate of lead are shown graphically in figure 21.

Arsenate of lead seed treatment resulted in the poorest stand even when rodents attacked the plantings.

The arsenate of lead seed treatment resulted in a highly significant reduction in stand of plants as compared with untreated seed and that treated with organic mercury dust, even when the planting was attacked by rodents. The rodents were especially active in the

second and fourth plantings in River field and to a lesser extent in the third planting. There was no rodent damage to the first planting in River field or to the planting on Las Mesas.

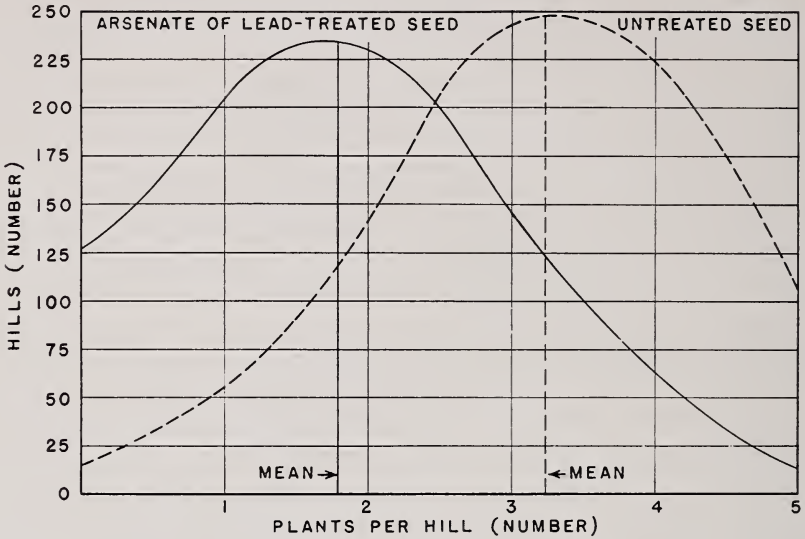

FIGURE 21.—Number of sweet corn plants per hill resulting from untreated seed and from seed treated with arsenate of lead.

Arsenate of lead seed treatment checked early growth of sweet corn.

In addition to causing a poorer stand of plants the arsenate of lead seed treatment also had an adverse effect on the early growth of the sweet corn. Soon after the plants came up it was noted that those from the arsenate of lead treated seed tended to be yellowish green in color rather than the darker green of the plants from untreated seed, and 2 weeks after planting differences in the size of the plants in the two treatments became apparent. While these differences were apparent in all six plantings they were much more noticeable in the lowland plantings than on Las Mesas.

As a check on these growth observations, 30 plants each from untreated seed and from those treated with arsenate of lead in the first River field experiment were harvested 35 days from planting. The harvested plants were placed in groups of 5 plants each according to their position in the field, dried in a greenhouse, and the air-dry weights of each group determined. In order that the plants from each treatment should be as comparable as possible, they were thinned to 1 plant per hill 2 weeks after planting, and no plant of one treatment was harvested unless there was a plant of the other treatment available for harvest in an adjacent hill.

The air-dry weight determinations revealed that the 30 plants from arsenate-treated seed averaged 9.04 grams each while those from untreated seed averaged 10.83 grams each, a difference of 19.8 percent in favor of the untreated seed. An analysis of the variance of the data revealed that this treatment difference was statistically significant; the odds were greater than 19 to 1 that the difference could not have arisen as a result of chance alone.

Arsenate of lead seed treatment for sweet corn is of questionable value.

Thus, under the conditions of these six experiments it has been statistically demonstrated that the arsenate of lead treatment of sweet corn seed to prevent rodent damage to the seed after planting brought about a reduction in stand of plants as compared with untreated seed even under conditions where considerable rodent damage occurred. It has been further demonstrated that in one of the experiments the use of arsenate of lead on the seed also resulted in reduced early growth of the plants. The results of these experiments indicate that the use of an arsenate of lead seed treatment to prevent rodent injury to sweet corn seed following planting is of questionable value and in some cases may even be detrimental.

Puerto Rico has a tariff advantage in the production of winter sweet corn.

Puerto Rico is the only place under the American flag where sweet corn can be grown during the winter months near enough to New York to make it possible to supply that market from November to April. There is a favorable protective tariff on sweet corn, only modified by a 20-percent preferential on sweet corn from Cuba.

CALABAZA BREEDING AND PROPAGATION STUDIES

Puerto Rico has no established varieties of calabazas.

In Puerto Rico there are no established varieties of calabazas (*Cucurbita* spp.). The different types found on the local markets are almost innumerable. The fruits vary greatly in shape, size, and color; and the flesh varies in color, texture, and thickness.

Experimental work with a large number of different types, and observations made during the past 3 years, have shown that there is a wide variability among them in yielding ability as well as in quality of fruits produced. Breeding studies have been started in an effort to isolate and fix certain of the most desirable high-quality, high-yielding types.

Cross-pollination is common with calabazas.

Calabaza plants are usually monoecious, pollination being effected by insects, mostly honeybees, and cross-pollination is common. Furthermore, there are no extensive plantings of calabazas on the island. Although widespread, calabaza production is confined chiefly to numerous small patches, and a few plants can be found growing around practically every rural home. Because of frequent cross-pollination and the type of plantings, together with the fact that there are no commercial seedsmen handling seed of the types of calabazas grown here, it would be somewhat difficult to maintain distinct varieties.

A method of vegetative propagation of calabazas has been developed.

During the past year a method of vegetative propagation for calabazas has been developed which makes it possible for any desirable type to be perpetuated indefinitely. Vigorous five- to seven-node cuttings with swollen root buds at several nodes have rooted and successfully established normal plants under field conditions; under favorable soil-moisture conditions in the field, successful propagation as high as 90 percent of the cuttings was not unusual. All leaves on

each cutting were left intact, the youngest leaf being usually about one-third grown. In planting, the cuttings were placed longitudinally in the soil with all parts covered except the youngest leaf and the buds subtended by it. No shading was required, nor was the application of growth-promoting substances or other special growth aids necessary. It was observed that plants thus propagated grew more rapidly and fruited earlier than plants produced from seed.

FIGURE 22.—A five-node calabaza cutting showing the rooting response and extent of new top growth 6 days after planting. The cuttings are placed longitudinally in the soil. This type of propagation offers a quick easy method for the improvement and standardization of calabaza types.

By making possible the immediate propagation of superior commercial types of greater uniformity and higher quality and the elimination of inferior quality low-yielding types, this method of propagation would seem to have an economic application not only in Puerto Rico but also in other tropical and subtropical regions where heterogeneous populations of squash exist.

Figure 22 shows something of the rooting response and extent of new top growth obtained with well-selected calabaza cuttings planted under favorable soil-moisture conditions. This cutting had been in the soil only 6 days.

CUCUMBER VARIETY TRIALS

Cucumbers are the leading winter-vegetable export crop of Puerto Rico.

At present cucumbers are the leading winter-vegetable export crop of Puerto Rico. However, the Black Diamond variety, which is most commonly grown for export, is susceptible to downy mildew; it is only by spraying the plants with bordeaux mixture at 3- to 5-day intervals from soon after the first true leaves develop until the end of the harvest season, that satisfactory yields can be obtained. Even with frequent spray-

ing the crop is considerably shorter than in many of the commercial producing areas on the continent.

The local cost of producing cucumbers during the winter months would be considerably less if a downy mildew-resistant variety that yielded a heavy crop of fruits acceptable to the continental markets could be made available. None of the commercial varieties offered for sale on the continent and tested here have met these requirements.

Indian cucumbers showed resistance to downy mildew.

It is of interest to workers engaged in developing disease-resistant varieties of cucumbers to record the results of some variety trials that were conducted at the station in the past 3 years. During this period more than 100 varieties and strains, obtained from many different parts of the world, were tested for their resistance to downy mildew along with the Black Diamond variety as a check. Included in this large collection were nine named varieties indigenous to India. Several of these grew vigorously, yielded well, and showed considerably more resistance to downy mildew than did the Black Diamond variety; however, the fruits were far from being of the accepted market type. While these mildew-resistant Indian cucumbers might make satisfactory home-garden varieties for Puerto Rico, a long-time program of breeding and selection would be necessary to develop from them an acceptable commercial variety carrying the factor for mildew resistance.

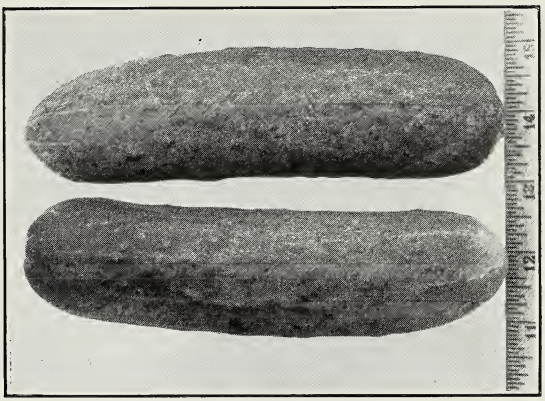

FIGURE 23.—Typical fruits of P. I. No. 116741, *Cucumis sativus*, from India, showing shape and color pattern of the fruits. This introduced cucumber variety shows considerable promise for Puerto Rico.

Most of the varieties tested were collected from different parts of the world and made available to the experiment station by the Division of Plant Exploration and Introduction of the Bureau of Plant Industry. A number of these unnamed strains and varieties showed varying degrees of resistance to downy mildew. Among these, one variety, listed as Plant Introduction No. 116741, showed considerable promise. The vines were exceptionally vigorous, fruited well, and remained green in the field without spraying about 2 to 3 weeks longer than Black Diamond. At the marketable stage, the fruits were uniformly 6 to 8 inches long, of medium diameter, and straight with somewhat rounded ends. The pericarp was thick and the flesh firm and tender, with only a trace of the pungency characteristic of many cucumbers.

While the shape and size of the fruits were almost ideal from the market standpoint, the color was not altogether satisfactory. Instead

of the solid green color preferred by the continental markets, the fruits were not uniformly green but shaded off into dull grayish green with an occasional small streak of white toward the blossom end. The shape and color pattern of the fruits of this promising cucumber are shown in figure 23.

New variety matures later than Black Diamond.

This variety is several days later than Black Diamond. While it is possible that the market would accept this cucumber as now grown, it is probable that a more satisfactory variety could be obtained by crossing P. I. No. 116741 with Black Diamond and then selecting a type in which the vigor, mildew resistance, and fruit shape of P. I. No. 116741 would be combined with the earliness, productiveness, and good fruit color of Black Diamond.

SWEETPOTATO BREEDING

Cooperative sweetpotato-breeding work was continued with the Bureau of Plant Industry.

Inasmuch as the sweetpotato does not normally flower and set seed in the continental United States, and flowering and seed production are common with many varieties in Puerto Rico, this station has been conducting a cooperative sweetpotato-breeding program with the Bureau of Plant Industry since 1935, using selected continental American varieties. During the past year the breeding plats were enlarged and four new varieties were added at the request of the Iowa Agricultural Experiment Station. The varieties included in the breeding program during the year were as follows: Big Stem Jersey, Black Rock, Introductions 22437, 47442, 64377, and 85986, Mameyita, Muscatine No. 1,[4] Prolific,[4] Porto Rico, Red Brazil,[4] Seedling 254, Vineland Bush, and Yellow Strasburg.[4]

Sweetpotato varieties varied widely in flowering response.

The main planting was made early in July, and a second planting that included the Iowa varieties as well as all the other varieties listed above, was made in September. The Porto Rico, Mamevita, Seedling 254, Introduction 85986, and Introduction 64377 varieties blossomed freely, the first blossoms appearing during the last week in October. All remaining varieties flowered sparingly. In general, plants of different varieties planted at the same time varied widely in their flowering responses; even plants within the same variety differed in this respect. In no variety did 100 percent of the plants blossom; some that formed blossom buds failed to produce blossoms. Not all blossom buds that formed on the same branch developed into blossoms, for many abscised during various stages of development. All branches of the same plant did not give the same flowering response. The blossoming behavior of the plants could not be associated with age or size of plant, either among varieties or among plants of the same variety.

[4] From Iowa Agricultural Experiment Station.

Fourteen thousand blossoms were tagged for pollination and seed-production studies.

More than 14,000 blossoms, involving all varieties except Red Brazil, were tagged for pollination studies and seed production. Approximately 1,300 seed resulted from this work; 300 of these were the result of various crosses and controlled self-pollinations, while the remaining 1,000 seed resulted from open-pollinations.

Most of the seed were produced during February, March, and April.

By far the largest proportion of the seed was produced during February, March, and April. Of the more than 2,500 blossoms tagged prior to December 7, only 42 developed into mature fruits, and of these 26 were produced on ringed branches. More than 3,700 blossoms were tagged from December 18 to January 24, but only 35 fruits containing 43 seed developed. Thus only 77 of more than 1,000 fruits produced resulted from blossoms opening before January 24.

The seed resulting from the few scattered flowers of the Iowa varieties were forwarded to the Iowa Agricultural Experiment Station, and the remainder of the seed was sent to the Bureau of Plant Industry for germination and testing.

Pollination treatments yielded interesting information.

The various pollination treatments employed in the breeding work with the continental varieties yielded some interesting results. The pollination treatments included allowing blossoms to be open-pollinated, self-pollination with blossoms left unprotected, self-pollination with blossoms covered, covering blossoms with no artificial pollination, and controlled crosses with various other varieties.

When the seed resulting from tagged blossoms were harvested, it was discovered that many plants on which blossoms had been tagged bore no fruit. Separate records were kept for each plant bearing tagged blossoms, thereby facilitating the separation of the results of plants bearing fruit from those of unfruitful plants. Since the physiological condition that causes flowering in sweetpotatoes might not necessarily be favorable for seed production, the discussion of the results of the pollination and seed-production studies which follows is based on the response of the plants which produced seed.

A number of varieties were self-sterile.

A summary of the results of the various pollination treatments on plants of several varieties is shown in table 24. It can be seen that the Porto Rico variety was highly self-sterile. On the other hand, a 34.8-percent set of fruit resulted when Introduction 64377 was used as the pollen parent, and a 27-percent set resulted from open-pollination.

TABLE 24.—*Fruit-setting response of tagged blossoms of sweetpotatoes with various pollination treatments*

Pollination treatment	Blossoms tagged—			
	On all plants		On plants setting fruit	
	Total	Setting fruit	Total	Setting fruit
PORTO RICO				
	Number	*Percent*	*Number*	*Percent*
Porto Rico open-pollinated	1,551	9.1	522	27.0
Porto Rico selfed, uncovered	317	10.7	124	27.4
Porto Rico selfed, covered	228	1.3	101	3.0
Porto Rico covered	405	1.0	156	2.6
Porto Rico × Introduction 64377	218	18.3	115	34.8
Porto Rico × Introduction 85986	135	.8	47	2.1
Porto Rico × Introduction 47442	24	4.2	12	8.3
Porto Rico × Introduction 22437	23	17.4	10	40.0
Porto Rico × Mameyita	339	0	119	0
Porto Rico × Seedling 254	85	12.9	52	21.2
Porto Rico × Vineland Bush	89	2.2	39	5.1
Porto Rico × Big Stem Jersey	19	0	3	0
Porto Rico × Black Rock	30	10.0	19	15.8
Porto Rico × Muscatine No. 1	30	10.0	17	17.6
Porto Rico × Prolific	133	0	44	0
Porto Rico × Yellow Strasburg	31	19.4	21	28.6
SEEDLING 254				
Seedling 254 open-pollinated	379	21.1	208	38.5
Seedling 254 selfed, uncovered	158	27.8	88	50.0
Seedling 254 selfed, covered	154	11.7	92	19.6
Seedling 254 covered	201	1.0	135	1.5
Seedling 254 × Porto Rico	265	.8	151	1.3
Seedling 254 × Vineland Bush	40	0	26	0
Seedling 254 × Big Stem Jersey	42	0	24	0
Seedling 254 × Prolific	28	7.1	10	20.0
Seedling 254 × Muscatine No. 1	6	16.7	6	16.7
Seedling 254 × Introduction 22437	4	0	1	0
MAMEYITA				
Mameyita open-pollinated	514	5.4	119	23.5
Mameyita selfed, uncovered	22	0	7	0
Mameyita selfed, covered	80	0	31	0
Mameyita covered	133	0	34	0
Mameyita×Porto Rico	100	0	24	0
Mameyita×Vineland Bush	62	1.7	11	9.1
INTRODUCTION 64377				
Introduction 64377 open-pollinated	386	7.5	120	24.2
Introduction 64377 selfed, uncovered	34	5.9	9	22.2
Introduction 64377 selfed, covered	71	0	31	0
Introduction 64377 covered	102	0	34	0
Introduction 64377×Porto Rico	173	4.6	32	25.0
Introduction 64377×Vineland Bush	40	5.0	12	16.7
INTRODUCTION 85986				
Introduction 85986 open-pollinated	561	4.3	134	17.9
Introduction 85986 selfed, uncovered	148	2.7	43	9.3
Introduction 85986 selfed, covered	59	1.7	45	2.2
Introduction 85986 covered	107	0	48	0
Introduction 85986×Porto Rico	121	.8	39	2.6
Introduction 85986×Vineland Bush	118	6.8	15	53.3

Seedling 254 was partially self-fertile, a 19.6-percent set of fruit resulting when the blossoms were selfed. The highest percentage set resulted from selfing plus open-pollination, followed by open-pollination with a percentage set of 38.5. Porto Rico pollen was not effective on Seedling 254 stigmas. Mameyita and Introductions 64377 and 85986 were almost completely self-sterile. Comparatively good sets of fruits resulted from open-pollination of blossoms of the three varieties. Porto Rico pollen was shown to be effective in seed production on Introduction 64377, giving a set of 25 percent.

Most open-pollinated seed were shown to be result of cross-pollination.

During the fiscal years 1936 and 1937 almost no insects that might effect cross-pollination in sweetpotatoes were observed visiting the blossoms. However, a number of seed resulting from open-pollination were produced. Since practically no insects were observed visiting the flowers, it was assumed that the open-pollinated seed resulted from natural self-pollination. In order to verify this, a number of controlled self-pollinations were made with five of the varieties included in the breeding plats. Table 25 gives a summary of the results of these controlled self-pollinations, together with results from the open-pollinations.

TABLE 25.—*Fruit-setting response of tagged self-pollinated blossoms and open-pollinated blossoms on fruit-bearing plants of different varieties of sweetpotatoes*

Variety	Blossoms tagged					
	Open-pollinated		Self-pollinated and covered		Covered	
	Total	Setting fruit	Total	Setting fruit	Total	Setting fruit
	Number	*Percent*	*Number*	*Percent*	*Number*	*Percent*
Introduction 64377	120	24.2	31	0	34	0
Introduction 85986	134	17.9	45	2.2	48	0
Mameyita	119	23.5	31	0	34	0
Porto Rico	522	27.0	101	3.0	156	2.6
Seedling 254	208	38.5	92	19.6	135	1.5

The tables show that the set resulting from the open-pollinations ranged from 17.9 percent with Introduction 85986 to 38.5 percent with Seedling 254. All varieties except Seedling 254 were almost completely self-sterile. The inference is, therefore, that with the possible exception of those of Seedling 254, most of the fruits resulting from open-pollination were the result of cross-pollination effected by insects.

As contrasted with the first two breeding seasons, insects were unusually plentiful during the past year. The honeybee was the most plentiful of those visiting the sweetpotato blossoms, but several other insects were also observed working among the flowers; three of these were identified as *Campsomeris dorsata* (F.),[5] *Megachile lanata* Fabr.,[5] and *Melissodes trifasciata* Cresson.[5] These three Hymenoptera were identified through the assistance of H. K. Plank, associate entomologist.

[5] Determined by Grace Sandhouse, Bureau of Entomology and Plant Quarantine.

Porto Rico pollen was incompatible except with Introduction 64377.

Of special interest were the results of reciprocal crosses between Porto Rico and four other sweetpotato varieties. From table 26, which shows the results of these reciprocal crosses, it will be noted that Introduction 85986 and Mameyita were incompatible with Porto Rico, whereas Introduction 64377 was compatible, the reciprocal cross resulting in a 34.8-percent set of fruit when Porto Rico was the pistillate parent and 25 percent when Introduction 64377 was the pistillate parent. Porto Rico pollen was incompatible with all varieties except Introduction 64377. The cross Porto Rico × Seedling 254 was effective in promoting a 21.2-percent set of fruit, but the reciprocal cross was not effective.

TABLE 26.—*Results of reciprocal crosses between the Porto Rico and four other varieties of sweetpotatoes* [1]

Crosses	Blossoms tagged	
	Total	Setting fruit
	Number	*Percent*
Porto Rico × Introduction 64377	115	34.8
Introduction 64377 × Porto Rico	32	25.0
Porto Rico × Seedling 254	52	21.2
Seedling 254 × Porto Rico	151	1.3
Porto Rico × Introduction 85986	47	2.1
Introduction 85986 × PortoRico	39	2.6
Porto Rico × Mameyita	119	0
Mameyita × Porto Rico	24	0

[1] Records from fruiting plants only.

Vineland Bush was a good pollen parent for Introductions 85986 and 64377.

Of interest also was the comparative effectiveness of Vineland Bush as a pollen parent for five of the other sweetpotato varieties included in the test. This information is shown in table 27. Vineland Bush was a poor pollen parent for Seedling 254, Porto Rico, and possibly Mameyita also; but it was compatible with Introductions 85986 and 64377 to the extent that a 53.3-percent and a 16.7-percent set of fruit was obtained, respectively.

TABLE 27.—*Relative efficiency of Vineland Bush pollen in inducing seed production on fruiting plants of 5 varieties of sweetpotatoes*

Crosses	Blossoms tagged	
	Total	Setting fruit
	Number	*Percent*
Introduction 64377 × Vineland Bush	12	16.7
Introduction 85986 × Vineland Bush	15	53.3
Mameyita × Vineland Bush	11	9.1
Porto Rico × Vineland Bush	39	5.1
Seedling 254 × Vineland Bush	26	0

Seed of Puerto Rican varieties of sweetpotatoes were forwarded to the Bureau of Plant Industry.

During the past year approximately 17,500 seed resulting from open-pollinated flowers of 10 Puerto Rican varieties of sweetpotatoes were collected and forwarded to the Bureau of Plant Industry for testing along with seedlings of the continental varieties. The local varieties from which seed were collected were Buena, Brava, Cachimba, Cayo Hueso, Cibuca, Don Juan, García, Miguela, Pichilinga, and Totiempo.

Many of the varieties of sweetpotatoes commonly grown in the continental United States have originated in the West Indies. Most sweetpotato plantings in Puerto Rico are of mixed varieties, and as a result of chance seedlings coming from seed of open-pollinated flowers, new forms are doubtless appearing from time to time. Therefore, in addition to the seed mentioned above, roots of the local varieties, Cachimba, Cibuca, Don Juan, García, and Miguela have been forwarded to the Bureau of Plant Industry where, after a period of quarantine, they will be released for testing on the continent.

Ninety-three varieties of sweetpotatoes have been received for testing.

Puerto Rico needs a high-yielding, good-quality, early variety of sweetpotato in order to escape the severe ravages of the sweetpotato weevils which damage roots and vines of late varieties. During the past year 93 unnamed seedling varieties of sweetpotatoes were received from the Bureau of Plant Industry for testing. Many of these seedlings appear to be well adapted to Puerto Rican conditions, and the propagating material from them has been increased for more extensive testing.

MISCELLANEOUS

Puerto Rican wild lima beans seem resistant to pod borers.

Lima beans of many different colors and, to a lesser extent, sizes and shapes grow wild in Puerto Rico. In the 1937 annual report the statement was made that pods of these wild lima beans have not been observed to be infested with pod borer species even when plants were growing beside a field of common field beans the pods of which were heavily infested. The susceptibility of this wild lima bean to attack by pod borers has not yet been tested at the station under controlled conditions. Nevertheless, its apparent resistance to pod borers has resulted in requests from the continental United States for seed.

Two lots of seed were forwarded to the Bureau of Plant Industry for testing and for distribution to other agencies interested in their suspected pod borer resistance.

Except where otherwise indicated these vegetable-crop investigations have been under the direction of Wallace K. Bailey.

TROPICAL FRUITS FOR EXPORT

Mangoes and avocados have import tax of 15 cents per pound.

Sugar and rum, which have a high tariff protection, are produced mostly by large landowners. Tobacco, with a high tariff protection, is produced in many cases by small planters. Other than sugar, rum, and tobacco, the agricultural products of Puerto Rico, particularly

those marketed by the small planter, do not have much tariff protection. On the other hand, the foodstuffs, hardware supplies, and other essentials that the small planter uses for the most part have a considerable import tax. Wage scales for agricultural labor are double, and even quadruple, those of some of the nearby islands of the West Indies and other countries of Central America and South America. Thus the small landowner of this island who produces agricultural products that have no tariff protection is following a formula for continuous financial losses. It is logical under these conditions to study the tariff schedules to find those crops suited for the island which have the advantage of tariff protection and which may be produced by the small planter.

Mangoes entering the United States from foreign countries other than Cuba pay an import tax of 15 cents per pound whereas those produced in Puerto Rico do not pay this tax. This is one of the tariff schedules in the Tariff Act of 1930, and has not been modified by any reciprocity treaty to date.

The mango tree thrives in the island, particularly in districts where rainfall is not excessive and the air not too humid. Many varieties of mangoes are susceptible to a fungus disease that causes considerable losses in wet districts but is rarely observed in the drier districts. Mangoes have proven to be highly resistant to drought and, by proper selection of resistant varieties and climatic conditions in which to grow them, may be produced cheaply by the small planter.

Some of the mango varieties at the experiment station have been frequently infested by larvae of a fruitfly (*Anastrepha mombinpraeoptans*). This fruitfly does not occur in the continental United States, and, therefore, the Federal plant-quarantine authorities have placed an embargo on the shipping of mangoes from Puerto Rico and other West Indian islands to the continental United States. However, as mentioned in the report of last year, mangoes have been sulfured and dried in such a way as to kill the larvae of the fruitfly.

During the year, experiments in canning mangoes have been carried on in cooperation with the American Can Co., but the results were not entirely successful as the mangoes lost a great deal of their distinctive flavor under the methods of canning tried.

Experiments by the Bureau of Entomology and Plant Quarantine hold possibilities for the treatment of the fresh fruits in such a way as to destroy the larvae of the fruitfly and thus permit the lifting of the embargo on mangoes from Puerto Rico to the continent.

During the year, all possible seeds of the best varieties in the station collection have been propagated; varieties have been selected on the basis of distinctive flavor, a minimum of fiber, and resistance to the fruitfly and the fungus disease anthracnose.

Removal of coverings from mango seeds doubled germination.

In work at the station in the extension of mango plantings, the seeds have yielded low percentages of germination. Trials without experimental checks gave some evidence that removal of the seed coats from the seed before planting considerably improved germination. A controlled experiment was therefore undertaken to establish more definite conclusions on this question. A lot of 385 mango seeds with all the coverings removed and an equal number of seeds with their coverings intact were planted in 10 alternating nursery rows. Obser-

vations were made on the number of seeds germinating and their subsequent growth; the results of these observations until 11 months after planting are shown in table 28.

TABLE 28.—*Germination of mango seeds with endocarps removed as compared with untreated seeds, and heights of the seedlings 11 months after planting* [1]

Treatment [2]	Germination	Height of seedlings		
		Maximum	Minimum	Average
	Percent	*Inches*	*Inches*	*Inches*
Seed coverings removed	47.8	61	8.0	24
Seed coverings intact	22.1	43	7.5	19

[1] Experiment by Claud Horn.
[2] 385 seeds in each treatment.

Not only was better germination obtained when the coverings were removed, but also the resulting seedlings developed to a greater average height than did those from the seeds not so treated.

Avocados are being planted and budded.

Because avocados grown in American territory have a tariff advantage of 15 cents per pound as compared with foreign countries other than Cuba,[6] the station has undertaken the study of avocado varieties and propagation. Many new varieties have been introduced by the station in years past and scion material is being taken from these mature trees for budding avocado seedlings.

Experience at the station has shown that the avocado in wet heavy clay soils is susceptible to a destructive root and trunk rot. Distributions of avocado nursery trees are, therefore, being made to the drier districts where soil aeration is good and where experience has shown that avocados develop well. The protected hillsides of the lower valleys inland from the south coast seem logical for the extension of plantings of avocados as well as mangoes, since these locations have not only drainage but also favorable atmospheric conditions and some degree of protection from hurricanes.

Fresh pineapples have tariff advantages.

Under the Tariff Act of 1930, there is an import tax on pineapples of 50 cents per standard pineapple crate of 2.45 cubic feet. In the reciprocal trade treaty with Cuba in 1934, the tariff on pineapples was reduced to 20 cents per standard crate, which rate, however, was not applicable to the entry of pineapples from other countries. In 1935 the reciprocal trade treaty with Haiti reduced the import tax on fresh pineapples from 50 cents to 35 cents per standard crate, and under the terms of the Trade Agreements Act this reduction in import tax was generalized to all tropical foreign countries producing pineapples excepting, of course, Cuba. Even in view of the reduced import taxes on fresh pineapples from foreign countries, Puerto Rico still has a material advantage in the marketing of this crop in the continental United States.

[6] Avocados imported into the United States from Cuba are free of duty, but by agreement Cuba does not permit the export of avocados to the United States other than during the period June 1 to September 30, inclusive.

Field-ripened pineapples have marketing advantages.

During the year experiments were carried on by C. O. Bratley, associate pathologist of the Bureau of Plant Industry, cooperating with William Pennock of this experiment station, to test the shipment of field-ripened pineapples under refrigeration to New York. The work was inaugurated because of the success obtained on the continent in marketing other fruits when field-ripened as compared with those harvested green and ripened in shipment or storage.

Detailed results cannot be presented here, but such preliminary experiments showed that pineapples to some extent field-ripened can be shipped to New York under refrigeration and can be held there for 7 days without serious losses from rotting. The results also showed that such pineapples with some degree of field ripening had a much more highly developed aroma and flavor than those picked by the ordinary standards as green. Although further studies are desirable, there is evidence to indicate that growers shipping pineapples with an advanced degree of maturity in the field will have considerable advantages in marketing as compared with growers continuing the present standards for shipping green fruits.

Work on tropical fruits for export has been carried on by Claud Horn, associate horticulturist, and William Pennock, assistant agronomist.

SUGARCANE INVESTIGATIONS

SUGARCANE VARIETIES AND SEED-PIECE DISTRIBUTION

Thirty-nine sugarcane varieties were distributed to growers.

The distribution of seed pieces of sugarcane varieties to interested planters was continued during the year. A total of 13,349 seed pieces of 39 varieties were distributed among 113 growers in Puerto Rico, the Virgin Islands, and four foreign countries.

Field trial of first ratoons of eight Mayaguez varieties was harvested.

In 1933, Luce & Co., of Aguirre, planted a small sugarcane variety test on Santa Isabel clay soil in cooperation with the experiment station and with seed pieces furnished by the station. This cooperative test, harvested in 1935, included eight Mayaguez varieties which were compared with B. H. 10 (12) as a standard variety. Because of the limited supply of seed pieces of the Mayaguez varieties available at that time, the trial was necessarily a preliminary one and consisted of a comparison of one $\frac{1}{20}$-acre plat of the Mayaguez varieties against four adjacent $\frac{1}{20}$-acre plats of B. H. 10 (12). The yield data thus obtained showed that all the Mayaguez varieties to some extent outyielded B. H. 10 (12) both in cane and sugar per acre. However, this orientation experiment gave only a rough indication of what might be expected in a larger experiment having replicated plats of greater size to overcome heterogeneity of soil conditions in a given field.

Since this trial was of limited value only, Luce & Co. undertook a larger experiment with these same varieties using the increased supply of seed pieces that had become available. This larger experiment, which was planted in the fall of 1935, was laid out in replicated $\frac{1}{10}$-acre plats, alternating the Mayaguez varieties with the standard B. H. 10 (12) in such a way that all the varieties were well distributed and well replicated throughout the field. The same cultural treatment was given to all the plats and each received the same amount of fertilizer.

The cane from each plat was cut, weighed, and milled separately. The first crop was harvested in 1937 as 16½-month-old plant cane and the second in 1938 as 14-month-old first-ratoon cane. The yield data from the two crops are presented in table 29.

TABLE 29.—*Comparative yields of sugarcane per acre, sucrose in juice, and sugar per acre in plant and first-ratoon crops of eight Mayaguez varieties tested on Santa Isabel clay at Salinas, 1937–38* [1]

Variety	Plant cane, 16½-month crop			First-ratoon cane, 14-month crop [2]		
	Cane	Sucrose in juice	Sugar	Cane	Sucrose in juice	Sugar
	Tons	*Percent*	*Tons*	*Tons*	*Percent*	*Tons*
M–255	81.67	15.6	9.40	53.89	16.20	6.37
M–260	85.88	15.4	9.30	48.50	17.57	6.27
M–261	80.59	15.7	9.30	49.97	18.23	6.66
M–266	82.26	15.6	9.50	49.28	16.97	6.17
M–269	80.30	15.4	8.62	48.99	17.43	6.27
M–270	82.75	15.1	9.11	52.03	16.70	6.37
M–317	86.37	16.2	10.38	53.89	18.03	7.15
M–318	83.53	15.1	9.30	49.77	16.73	6.17
B. H. 10 (12)	80.59	15.6	9.30	47.62	18.23	6.37

[1] Experiment by M. S. Baker and L. A. Roqué, Luce & Co., Aguirre, P. R. Planted Sept. 18, 1935; harvested Feb. 3, 1937.
[2] Ratooned Feb. 3, 1937; harvested Apr. 2, 1938.

Three Mayaguez varieties outyielded B. H. 10 (12) in sugar per acre in the plant crop.

Table 29 shows that six of the eight Mayaguez varieties in the test produced more plant cane per acre than the standard variety B. H. 10 (12); M–261 produced the same as the standard and M–269 less. Only M–269 and M–270 produced less sugar per acre than B. H. 10 (12); the rest produced an equal or a greater amount. M–317, which yielded 5.78 tons more cane, produced 1.08 tons more sugar per acre than the standard in this plant-cane test.

Two Mayaguez varieties produced more sugar per acre than B. H. 10 (12) in the first-ratoon crop.

The experiment was continued with the first ratoons and harvested in 1938. The yield data for the first-ratoon crop are shown in table 29. Of the eight Mayaguez varieties, M–261 and M–317 yielded greater amounts of sugar per acre than B. H. 10 (12) in the first-ratoon crop; two others, M–255 and M–270, produced the same amounts of sugar, while the remaining four yielded less.

Of the eight Mayaguez varieties tested M–317 outyielded B. H. 10 (12) in cane tonnage both in the plant and ratoon crops; M–317 had better juices in the plant crop but slightly poorer juices than B. H. 10 (12) in the first-ratoon crop. In both plant and first-ratoon crops M–317 outyielded B. H. 10 (12) in sugar per acre, the increased yield amounting to 1.86 tons for the two crops combined.

None of the other Mayaguez varieties was markedly superior to B. H. 10 (12) and only M–269 was noticeably inferior. All of the other varieties are worthy of being watched in other environments for possible differences in susceptibility to weeds, diseases, drought, or similar hazards.

SUGARCANE FERTILIZER EXPERIMENTS

Cooperative sugarcane fertilizer experiments were completed on two different soils.

Fertilizer experiments were conducted during the year on two types of soil with the sugarcane variety P. O. J. 2878 in cooperation with Central Eureka on the western end of the island. The central supplied the land, labor, and materials, and the experiment station supervised the operations. A fertilizer-constituent test and a nitrogen-quantity test were each conducted on Cataño sandy loam at Añasco and on Toa clay at Hormigueros.

In all four tests the plats were one-tenth of an acre in size and all treatments were replicated six times. There were four treatments in the fertilizer-constituent tests and five in the nitrogen-quantity tests. The cane from each plat was cut, weighed, and milled, and the respective juices analyzed separately.

Irrigation water was supplied to plats on Toa clay at Hormigueros.

Both the fertilizer-constituent test and the nitrogen-quantity test on Toa clay at Hormigueros were irrigated when the rainfall was not deemed sufficient. These plats received approximately 1 inch of irrigation water on February 18 and again on March 18, 1937.

At Añasco, where the tests were made on Cataño sandy loam, the mean monthly rainfall during the period of the experiment was 4.29 inches. Although the amount of rainfall here was somewhat less than that at Hormigueros the cane was not irrigated.

Ninety pounds of each nutrient constituent were applied per acre.

The fertilizer-constituent tests were planned to compare the effectiveness of nitrogen, phosphoric acid, and potash in various combinations of constant quantities of each constituent. The fertilizer treatments, constituents, and amounts of each applied per acre are shown in table 30.

TABLE 30.—*Fertilizer constituents, source of N, P_2O_5, K_2O, and quantities of each applied per acre by treatments in P. O. J. 2878 sugarcane fertilizer experiment on Cataño sandy loam and Toa clay, 1937–38*

Lot	Treatment	Fertilizer per acre					
		Constituents			Carriers		
		N	P_2O_5	K_2O	Ammonium sulfate	Calcium superphosphate	Potassium sulfate
		Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
A	Nitrogen	90	0	0	450	0	0
B	Nitrogen plus phosphoric acid	90	90	0	450	450	0
C	Nitrogen plus potash	90	0	90	450	0	180
D	Nitrogen plus phosphoric acid plus potash	90	90	90	450	450	180

The Cataño sandy loam field at Añasco had been planted to sugarcane in 1935 and had received 1,000 pounds of 13–5–10 fertilizer per acre. After having remained idle in 1936 the area was plowed in January and the experiment was planted February 1, 1937.

Because the field containing this experiment was divided into two parts, it was necessary to use plats of two different dimensions although all plats were of the same area. Each of the two parts contained three replications of each of the four treatments. In one section of the field the plats were 74.46 feet long and 58.5 feet wide, and in the other section 80.66 feet long and 54 feet wide, giving a total of twenty-four $\frac{1}{10}$-acre plats for the experiment. In both parts drainage ditches served as guards between plats. The rows were spaced 4.5 feet apart, giving 13 rows per plat in one section and 12 in the other.

The yield data from the various treatments in this experiment at Añasco are presented in table 31.

TABLE 31.—*Yield data of sugarcane fertilizer-constituent test with P. O. J. 2878 on Cataño sandy loam at Añasco, 1937–38* [1]

Lot	Treatment	Juice analyses			Yield per acre	
		Brix	Sucrose	Purity	Cane	Sugar
		Degrees	*Percent*	*Percent*	*Tons*	*Tons*
A	Nitrogen	18.72	15.63	83.57	46.00	5.38
B	Nitrogen plus phosphoric acid	18.87	15.98	84.68	48.29	5.85
C	Nitrogen plus potash	18.52	15.80	84.77	47.38	5.77
D	Nitrogen plus phosphoric acid plus potash	18.18	15.20	83.60	49.92	5.66

[1] Planned and laid out by J. H. Jensen. Juice analyses and sugar calculations by H. Pabón. Harvested by A. G. Kevorkian. Planted Feb. 1, 1937; fertilized Mar. 10, 1937; harvested Mar. 7 to 10, 1938; age at harvest, 13 months.

Phosphoric acid and potash did not significantly increase yield of cane or sugar.

The complete-fertilizer treatment produced the greatest tonnage of cane. Furthermore, there was a slight increase in yield when phosphoric acid was added to nitrogen and a slightly smaller increase with the addition of potash to nitrogen. In no treatment, however, was the increased tonnage statistically significant as is shown in table 32, which contains the analysis of variance for the yield data in table 31; neither potash nor phosphoric acid significantly increased Brix reading, sucrose content, purity of the juices, or sugar yield per acre.

TABLE 32.—*Analyses of variance of yield data obtained from sugarcane fertilizer-constituent test on Cataño sandy loam at Añasco, 1937–38*

Source of variance	Degrees of freedom	Mean squares				
		Juice analyses			Yields per acre	
		Brix	Sucrose	Purity	Cane	Sugar
Total	23	0.89	1.14	6.27	33.47	.77
Replications	5	.63	1.43	14.56	61.66	1.71
Treatments	3	.52	.67	2.61	16.13	.25
Error	15	1.06	1.13	4.23	27.55	.56
F value for treatments [1]		.49	.59	.62	.59	.44

[1] *F* value of 3.29 is necessary to give odds of 19 to 1 that differences among treatments were due to some factor other than chance. Odds of less than 19 to 1 were considered not significant.

Fertilizer constituents were tested on Toa clay at Hormigueros.

In a similar manner fertilizer constituents were tested on Toa clay at Hormigueros. The field under experimentation had been planted to sugarcane in 1936 and had been uniformly fertilized throughout. The field was plowed in late January and planted February 15, 1937. The twenty-four $\frac{1}{10}$-acre plats were 86.08 feet long and 50.6 feet wide; each plat contained 11 rows of cane spaced 4.6 feet apart. The harvest results are shown in table 33 and the statistical analyses for these data are contained in table 34.

TABLE 33.—*Yield data of sugarcane fertilizer-constituent test with P. O. J. 2878 on Toa clay at Hormigueros, 1937–38* [1]

Lot	Treatment	Juice analyses			Yields per acre	
		Brix	Sucrose	Purity	Cane	Sugar
		Degrees	*Percent*	*Percent*	*Tons*	*Tons*
A	Nitrogen	20.53	17.85	86.87	33.47	4.79
B	Nitrogen plus phosphoric acid	21.13	17.97	84.93	33.80	4.57
C	Nitrogen plus potash	20.43	17.60	85.75	36.87	4.87
D	Nitrogen plus phosphoric acid plus potash	20.70	16.06	87.18	37.41	5.13
Difference necessary for odds of 19 to 1		[2]	[2]	[2]	2.58	[2]
Difference necessary for odds of 99 to 1		[2]	[2]	[2]	3.57	[2]

[1] Planned and laid out by J. H. Jensen. Juice analyses and sugar calculations by H. Pabón. Harvested by A. G. Kevorkian. Planted Feb. 15, 1937; fertilized Mar. 2, 1937; harvested Mar. 16 and 17, 1938; age at harvest, 13 months.

[2] Treatment differences were not significant.

TABLE 34.—*Analyses of variance of yield data obtained from fertilizer-constituent test on Toa clay at Hormigueros, 1937–38*

Source of variance	Degrees of freedom	Mean squares				
		Juice analyses			Yields per acre	
		Brix	Sucrose	Purity	Cane	Sugar
Total	23	0.46	1.47	52.89	32.06	0.17
Replications	5	.76	3.05	24.53	33.28	.18
Treatments	3	.57	.37	6.35	15.61	.32
Error	15	.33	1.16	71.66	4.42	.13
F value for treatment [1]		1.76	.32	.08	3.53	2.46

[1] *F* value of 3.29 is necessary to give odds of 19 to 1 and 5.42 for odds of 99 to 1 that differences among treatments were due to some factor other than chance. Odds less than 19 to 1 considered not significant.

Potash applications gave increased cane tonnage.

In this test on Toa clay none of the fertilizer treatments gave statistically significant increases in Brix, sucrose content, or purity of juices. In cane tonnage, however, although there was no significant increased yield from phosphoric acid, there were significant increases where potash was added; these increases amounted to 3.4 tons of cane when nitrogen plus potash was compared with nitrogen alone, and 3.61 tons of cane when nitrogen plus phosphoric acid plus potash was compared with nitrogen plus phosphoric acid.

Although the increased cane tonnage resulted in increased sugar per acre, amounting to 0.34 ton in one case, such difference was not statistically significant.

Nitrogen-quantity tests were also conducted on Cataño sandy loam and Toa clay.

Two sugarcane nitrogen-quantity tests were conducted to determine the effect of five different quantities of nitrogen when used in combination with constant quantities of phosphorus and potassium. Nitrogen was varied in the different treatments from 0 to 150 pounds per acre. The treatments and the fertilizer constituents used in these two nitrogen-quantity tests are shown in table 35.

TABLE 35.—*Sources and quantities of nitrogen and fertilizer constituents used in nitrogen-quantity test with sugarcane variety P. O. J. 2878 on Cataño sandy loam and Toa clay, 1937–38*

Lot	Nitrogen per acre	Fertilizer per acre			Lot	Nitrogen per acre	Fertilizer per acre		
		Ammonium sulfate	Calcium superphosphate	Potassium sulfate			Ammonium sulfate	Calcium superphosphate	Potassium sulfate
	Pounds	*Pounds*	*Pounds*	*Pounds*		*Pounds*	*Pounds*	*Pounds*	*Pounds*
A	60	300	300	120	D	150	750	300	120
B	90	450	300	120	E	0	0	300	120
C	120	600	300	120					

The first of the nitrogen-quantity tests was located on Cataño sandy loam at Añasco. Cane had been cropped in this field fairly continuously in past years, but the field had remained idle during 1936; for this test it was plowed and planted in January 1937. For each nitrogen treatment there were six $\frac{1}{10}$-acre plats, each plat measuring 60.5 feet by 72 feet with 16 rows of cane per plat and 4.5 feet between rows. Table 36 contains the harvest results, and the statistical analyses for these data are shown in table 37.

TABLE 36.—*Yield data of nitrogen-quantity test with P. O. J. 2878 sugarcane on Cataño sandy loam at Añasco, 1937–38* [1]

Lot	Treatment		Juice analyses			Yields per acre	
	Nitrogen per acre	Ammonium sulfate per acre	Brix	Sucrose	Purity	Cane	Sugar
	Pounds	*Pounds*	*Degrees*	*Percent*	*Percent*	*Tons*	*Tons*
A	60	300	18.68	15.47	82.60	45.62	5.26
B	90	450	18.06	14.55	80.63	47.43	5.07
C	120	600	18.38	15.21	82.70	44.92	5.06
D	150	750	17.53	13.81	78.78	48.39	4.81
E	0	0	18.65	15.38	82.50	44.69	5.10
Difference necessary for odds of 19 to 1			(2)	1.14	(2)	(2)	(2)
Difference necessary for odds of 99 to 1			(2)	1.56	(2)	(2)	(2)

[1] Planned and laid out by J. H. Jensen. Juice analyses and sugar calculations by H. Pabón. Harvested by A. G. Kevorkian. Planted Jan. 21–28, 1937; fertilized Mar. 8, 1937; harvested Mar. 10–14, 1938; age at harvest, 13½ months.

[2] Treatment differences were not significant.

TABLE 37.—*Analyses of variance of yield data obtained from sugarcane nitrogen-quantity test on Cataño sandy loam at Añasco, 1937–38*

Source of variance	Degrees of freedom	Mean squares				
		Juice analyses			Yields per acre	
		Brix	Sucrose	Purity	Cane	Sugar
Total	29	6.27	1.15	9.22	15.42	4.00
Replications	5	.23	.52	9.00	48.68	1.29
Treatments	4	1.37	3.21	17.65	15.85	.15
Error	20	8.76	.90	7.59	7.03	.23
F value for treatments [1]		.16	3.57	2.33	2.25	.65

[1] *F* value of 2.87 is necessary to give odds of 19 to 1 that differences among treatments were due to some factor other than chance. Odds less than 19 to 1 considered not significant.

Increased nitrogen applications increased cane tonnage.

The harvest results show that there was a slightly upward trend in cane tonnage as applications of nitrogen were increased except in the 120-pound treatment which was only slightly higher than the no-nitrogen treatment. However, these differences in cane tonnage were not statistically significant since the *F* value for treatments, shown in table 41, was less than that required to give odds of 19 to 1 that differences among treatments were due to some factor other than chance.

Juice qualities were lowered with increasing quantities of nitrogen.

As regards the Brix of the cane juices, there was a gradual downward trend in the density of the juices with increasing quantities of nitrogen, although such differences were not statistically significant. There was also a trend toward decrease in the sucrose content of the juices with increased applications of nitrogen, and these differences were highly significant statistically in the case of the larger applications of nitrogen as compared to the no-nitrogen application.

Because of the poorer juice qualities, the increased quantities of nitrogen showed no increased yield of sugar per acre, but on the contrary there was a gradual lowering of sugar yield with increased quantities of nitrogen. This decrease in sugar yields, however, was not statistically significant.

Results of nitrogen quantity test on Toa clay were similar to those on Cataño sandy loam.

The second nitrogen-quantity test was located on Toa clay at Hormigueros. The $\frac{1}{10}$-acre plats were 80.66 feet long by 54 feet wide and contained 12 rows of cane spaced 4.5 feet apart. The results secured at harvesttime are presented in table 38 and the statistical analyses of the yield data for this table are shown in table 39.

TABLE 38.—*Yield data of sugarcane nitrogen-quantity test with P. O. J. 2878 on Toa clay at Hormigueros, 1937–38* [1]

Lot	Treatment		Juice analysis			Yields per acre	
	Nitrogen per acre	Ammonium sulfate per acre	Brix	Sucrose	Purity	Cane	Sugar
	Pounds	*Pounds*	*Degrees*	*Percent*	*Percent*	*Tons*	*Tons*
A	60	300	19.25	15.70	81.50	45.13	5.21
B	90	450	19.28	15.80	81.97	43.36	5.04
C	120	600	19.32	15.67	81.07	43.98	5.05
D	150	760	19.37	15.85	81.87	46.38	5.43
E	0	0	19.60	16.70	82.11	41.91	5.03

[1] Laid out by J. H. Jensen. Juice analyses and sugar calculations by H. Pabón. Harvested by A. G. Kevorkian. Planted Feb. 15, fertilized Mar. 1, 1937; harvested Mar. 14–15, 1938; age at harvest, 13 months.

TABLE 39.—*Analyses of variance of yield data obtained from sugarcane nitrogen-quantity test on Toa clay at Hormigueros, 1937–38*

Source of variance	Degrees of freedom	Mean squares				
		Juice analyses			Yields per acre	
		Brix	Sucrose	Purity	Cane	Sugar
Total	29	0.40	0.83	5.26	9.50	0.16
Replications	5	1.46	2.65	12.01	12.28	.27
Treatments	4	.11	.31	1.07	17.45	.17
Error	20	.19	.48	4.41	7.22	.13
F value for treatments [1]		.62	.64	.24	2.41	1.30

[1] *F* value of 2.87 is necessary to give odds of 19 to 1 that differences among treatments were due to some factor other than chance. Odds less than 19 to 1 considered not significant.

Increased nitrogen applications increased cane tonnage but lowered juice qualities.

In this test on Toa clay, nitrogen lowered the Brix, sucrose content, and purity of the juices, but in no case were the differences statistically significant. However, the addition of nitrogen gave slight increases in cane tonnage as compared to the plats receiving no nitrogen, although these increases were not statistically significant. Because of the lowered juice qualities, the increased cane tonnage did not give significant differences in sugar yields between the different treatments, nor did the slightly increased sugar yields as a result of such nitrogen applications pay for the cost of the fertilizer.

These results are not in agreement with many years of experience in many sugarcane countries and should not be applied to plantation practice in Puerto Rico without further confirmation and a more complete understanding of the factors involved.

Appreciation is expressed to Luce & Co. and to Central Eureka for the fine cooperation extended in carrying on these experiments.

Arthur G. Kevorkian, scientific aide, has been in charge of the sugarcane investigations during the year.

PLANT INTRODUCTIONS AND DISTRIBUTIONS

Many new plants were brought into the island during the year.

During the year valuable species and varieties of plants of economic and ornamental value were added to the rapidly increasing collection in the station's plant-introduction garden. Those plants of which propagating material was received have been classified as 5 species of cover and forage crops, 8 of essential-oil plants, 2 of shade trees, 17 fruit trees, 2 timber trees, 29 palms, 14 spice plants, and 7 miscellaneous species. In most cases these plants were received in exchange for planting material of Puerto Rican plants.

New plants received serve many useful purposes.

Plants of the tonka-bean (*Coumarouna odorata*) are now growing well at the station from seeds received from South America. The tree is leguminous and bears pods about 3 inches long each of which contains a single large seed that is the bean of commerce. In curing, the seeds are soaked in rum for several days. After the rum is drained off, there soon appears on the surface of the seeds a white crystalline

deposit of coumarin which is the most important constituent of the bean. It is the coumarin which gives to the beans the scent and flavor which are valued, resembling somewhat that of vanilla or new-mown hay. Tonka-beans are used in perfumery and for flavoring tobacco, confectionery, and in such liqueurs as benedictine. The beans are sometimes used as a substitute for vanilla flavoring. The present sources of tonka-beans for the United States are Trinidad, Venezuela, and Brazil. In addition to providing a source of supply of the beans, it is possible that this tree may be useful as shade in the coffee and vanilla plantations in the moist districts of the island.

Pogostemon cablin, a perfume plant, has been established at the station through seeds received in exchanges with the Philippine Bureau of Plant Industry. This valuable oriental plant is so rarely propagated through seeds that the possibility of obtaining the species except by cuttings was doubtful. The leaf of this member of the mint family yields the essential oil of patchouli, useful in perfume manufacture. Since many other members of this family grow well here,

FIGURE 24.—This one plant of the giant-leaved regal waterlily *Victoria regia*, the predominating feature of the water garden, is new to Puerto Rico.

some becoming noxious weeds, it is expected that patchouli will be of easy culture.

The magnificent waterlily *Victoria regia* was established in the aquatic garden from seeds received from the Botanic Garden, British Guiana, and is shown in figure 24. The huge, round, floating leaves, 4 feet or more in diameter, have the margins turned up at right angles to the water surface to a height of 3 inches or more to form a straight-sided basin. The unusual strength of the trussed formation of the spiny ribbing on the under side of the leaves permits them to support great weight. In an actual test with plants grown in the garden, a leaf 51 inches in diameter supported 70 pounds of evenly distributed sand without being submerged. The support of greater weights has been reported by workers elsewhere. The long petioles adapt the leaves well to quiet surfaces of streams or other bodies of water where there are fluctuations in depth. This feature should make this plant suitable for planting in the many storage reservoirs of the irrigation systems in the island, as these reservoirs are subject to consider-

able daily variations in depth. This plant bears beautiful flowers, 10 inches in diameter, which open on two successive nights and are at first white but later change to pink.

Aleurites cordata, a subtropical tung-oil producer, has made good growth.

Aleurites cordata, introduced last year, has grown rapidly. The seeds of this species produce one of the quick-drying oils used extensively in

FIGURE 25.—A 2-year-old specimen of *Aleurites cordata*, in the plant-introduction garden. This subtropical species produces one of the quick-drying industrial oils used in paints and varnishes.

the manufacture of paints and varnishes. The oil is much like that yielded by *A. montana* and the more hardy *A. fordii* from southeastern China and French Indo-China. By July 1938 the specimen shown in figure 25 reached a height of 7 feet. This species, which is native to southeastern Asia and nearby islands, is cultivated commercially in southern Japan.

Aleurites trisperma, another species producing one of the tung oils of commerce, again produced an abundant crop of soft-shelled nuts. Five hundred and fifty seedlings of this species were grown during the year; 100 seedlings were used to extend a 1-acre planting on the station grounds, while the others were planted in different environments by the United States Forest Service, on lands of the Caribbean National Forest, and at Carite, Cayey, and Guajataca. Through such distribution of plantings it will be possible to determine the adaptability of this species as a possible new crop for the island.

FIGURE 26.—A stem of Oiticica (*Licania rigida*) showing profuse root initiation 28 days after treatment with an indolebutyric acid preparation.

A single specimen of another new paint-oil-producing tropical tree (*Licania rigida*), the Oiticica, was permanently planted in the introduction garden in July 1937. This specimen has now reached a height of 7 feet. This brittle-leaved member of the almond family is native in dry northern Brazil, where in old age it becomes a spreading tree as much as 100 feet high. The thin-shelled 1½-inch fruit contains a single red-colored seed that yields about 60 percent of a light-colored oil closely resembling tung oil. Five plants were successfully propagated from this plant by means of marcottage or air layering. At the time of the application of the marcottage boxes a ring of bark one-eighth of an inch wide and deep enough to reach the cambium layer was removed at the point of application. The marcottage boxes were filled with damp granulated peat and approximately this moisture content was maintained throughout the experiment. Thirty-one days after the boxes were applied a profuse callousing had developed where the ring of bark was removed but no rooting had begun. At that time a light application of a preparation containing 2 milligrams of indolebutyric acid per gram of lanolin was made to the newly developed callus. Twenty-eight

days later profuse rooting was noted to have been initiated, as shown in figure 26. The rooted branches were severed from the mother plant and soon became well established in the soil.

Ground covers beautify gardens and stabilize soil.

Many tropical gardens need further use of low-growing, ground-covering plants in shaded areas where lawngrasses fail to grow. Such covers are desirable because they not only add to the attractiveness

FIGURE 27.—Effect of 8-month-old planting of ground covers in the plant-introduction garden. *Scindapsus aureus* occupies the right foreground, *Nephthytis afzelii* the midbackground and the tree trunk, while *Mondo japonicum*, recently planted, occupies the left foreground.

of the garden but also lessen soil erosion. Several decorative plants have been observed to be good ground covers, and plantings of them were extended during the year. The ornamental effectiveness of some of these plants is illustrated in figure 27. *Nephthytis afzelii*, a long trailing or climbing aroid vine, has two leaf forms. Those leaves that develop from the trailing stems are arrow-shaped and about 9 inches across, while those from climbing stems are deeply three-, five-, or seven-lobed. This green-foliaged vine forms a densely matted ground cover about 12 inches deep. Such robust-growing cover as this is best suited to areas of several hundred square feet in extent.

Scindapsus (*Pothos*) *aureus* is another aroid vine having heart-shaped, yellow- and green-blotched leaves. This vine has habits similar to *Nephthytis afzelii*, except that the cover formed by it is not so deep. *Philodendron nechodomi*, endemic to the Luquillo Mountains of Puerto Rico, and the delicious monster (*Monstera deliciosa*) have deeply cut leaves and both make robust covers that are not so dense as some of the smaller-leaved plants. In addition to the attractive foliage, the delicious monster produces clusters of pure white flowers of beautiful, firm texture, as illustrated in figure 28.

FIGURE 28.—A terminal stem of the Central American ornamental vine, the delicious monster (*Monstera deliciosa*) showing flower and flower-bud cluster.

The flowers are followed by cucumber-shaped edible fruits. Stems of the delicious monster are now being exported to the United States to be used as cuttings by greenhouse nurserymen to supply the trade with this valuable foliage plant in pots. Plantings of this luxuriant vine were extended to a shady hillside to be used as a parent area for further propagation. *Philodendron nechodomi* is not so robust as is the delicious monster, but its smaller foliage makes it more suitable in crowded areas.

In places requiring low-growing and trailing ground covers, the small cohitre (*Callisia repens*) gives a tight, fine-textured effect. It forms suitable lawns in shaded areas where most lawngrasses will not grow.

Several bulbous plants form good ground covers.

The sod-forming lily-turf (*Mondo japonicum*) has grown well both at Mayaguez and at Castañer. The leaves of this lily are dark green and produce a deep color effect when used as a ground cover. Although its flowers are lilac colored, they are small and borne near the ground and hence not readily seen within the leaves, which reach a height of about 1 foot.

The zephyrlilies have been observed to form dense mats, and areas planted to two species were extended during the year. The white zephyrlily (*Zephyranthes tubispatha*) and the dark pink zephyrlily (*Z. rosea*) have each escaped from cultivation and are found in fields of only occasional cultivation. These profuse-flowering plants are most effective when planted in masses. Being bulbous they are of easy propagation and withstand drought well.

The robust vines, such as the delicious monster and *Scindapsus aureus*, form effective garden features when permitted to climb the trunks of tall trees and clothe their hosts with their striking foliage. The crown-shaft palms, such as the royal palm, are well adapted to such trunk covers, because the long, clasping leaf sheaths of these palms, in being shed periodically with the leaves, keep the vines from reaching and smothering the crown.

Seedlings of mango varieties were supplied for planting in cooperative proving groves.

Continuing the extension of plantings of superior mango varieties in the best suited environments of the island, as indicated in the 1937 annual report, 1,203 seedlings of various good varieties were supplied for planting in cooperative groves. Two objectives are met in this mango-planting program, direct improvement in the quality of the Puerto Rican mango fruit crop, and provision for selection of new varieties among those trees that show desirable variation from their parents.

Plants and plant materials were distributed during the year.

A total of 47,399 plants and plant materials were propagated and distributed by the station during the year. The kinds and numbers distributed are shown by months in table 40.

TABLE 40.—*Economic and ornamental plants distributed by the station during the fiscal year 1938*

Item	July	August	September	October	November	December	January	February	March	April	May	June	Total
Plants:	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*
Avocado varieties		15	15	17									47
Bamboo species		13	10			225	10	6	6		202		472
Buginvillea varieties	32	31	47	212	32	236	117	166	108	310	54	47	1,392
Cactus species	34	28	29	35		21	148	158	264	33	70	78	898
Citrus varieties			90		21		1		3	2			117
Hibiscus varieties	967	581	9,774	1,325	3,781	942	3,297	3,288	972	976	971	426	27,300
Mango varieties	64	31	24	36	274	547	11				121	95	1,203
Miscellaneous economic plants	181	528	91	80	983	510	27	44	39	28		30	2,541
Miscellaneous fruit plants	478	752	105	111	144	96	60	65	232	46	72	65	2,226
Miscellaneous ornamental plants					449		76			102	32		659
Ornamental shrubs	264	436	449	857		357	498	1,443	147	339	52	271	5,113
Ornamental trees	404	48	182	103		53	108	86	118	91	315	281	1,789
Ornamental vines	497	64	134	40		91	113	279	51	267	193	84	1,813
Palms	87	81	143	69	112	40	174	112	89	122	107	191	1,327
Waterlily plants	12	10	2	6	12	22	16	10	12	26	44	16	188
Waxflower plants		9	10		97	101	2	9	17	17	24	28	314
Total	3,020	2,627	11,105	2,891	5,905	3,241	4,658	5,666	2,058	2,359	2,257	1,612	47,399
Seeds:	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*
Cacao									2				2
Cannon-ball tree									2				2
Coffee						1			2	1	1		5
Oncoba echinata								¼					¼
Ornamentals										1	1½		2½
Palms									3½				3½
Total						1		¼	9½	2	2½		15¼

New plants that had grown well on the station grounds were distributed together with plants that were of common occurrence in Puerto Rico. Over 4,000 were of economic value. Some were exchanged for new plants from the continent or other countries, but most were distributed for local planting to assist in crop improvement throughout the island.

By the propagation of many ornamentals and their local distribution not only to individuals but also to other governmental agencies, the station continued its long-standing policy of assisting in the beautification of the island through planned planting. Two governmental agencies that received much of this material and used it in this way were the Puerto Rico Reconstruction Administration and the Forest Service of the United States Department of Agriculture. The number and kinds of plants distributed to these agencies are shown in table 41.

Claud L. Horn, associate horticulturist, has continued in charge of plant introductions and distributions during the year.

TABLE 41.—*Ornamental and economic plants distributed to the Puerto Rico Reconstruction Administration and United States Forest Service during 1937–38*

PUERTO RICO RECONSTRUCTION ADMINISTRATION

Item	July	August	September	October	November	December	January	February	March	April	May	June	Total
Plants:	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*
Bamboo species				4								200	204
Buginvillea varieties	5			290		12	15	12		4			338
Cactus species						8							8
Hibiscus varieties		100		2,025	200	8	500	500	1,000		100		4,433
Mango varieties						200	4						204
Miscellaneous economic plants	5	10	5	837			37	12		24			930
Miscellaneous fruit plants				26			26	10					62
Miscellaneous ornamental plants	5			235			12	704					956
Ornamental trees and shrubs				875			462				150		1,487
Ornamental vines	15		15	675			32						737
Palms	20		20	166		4	31	16					257
Total	50	110	40	5,133	200	232	1,119	1,254	1,000	28	250	200	9,616

UNITED STATES FOREST SERVICE

Buginvillea varieties	16	10											26
Cactus species	20												20
Hibiscus varieties	20												20
Mango varieties						65							65
Miscellaneous economic plants						350							350
Ornamental trees and shrubs	42												42
Ornamental vines	50		40										90
Total	148	10	40			415							613

BIOLOGICAL CONTROL ACTIVITIES

Cooperation was received from many sources in the introduction of beneficial insects.

The introduction and colonization of beneficial insect species, mentioned in the last report, was continued during the year. Through a cooperative agreement with the Bureau of Entomology and Plant

Quarantine, the station was able to obtain new and promising species; the station in turn provided indigenous and newly established species for liberation in the continental United States. A trip to Trinidad and South America resulted in the introduction of a number of new parasites and predators and furthered cordial relations with the British colonies with whom cooperation was carried on in the exchange of beneficial insects.

The Board of Commissioners of Agriculture and Forestry of Hawaii continued its generous cooperation with numerous shipments of beneficial insects. The Government of Cuba also generously provided a number of shipments of predatory coccinellid beetles. Shipments of the toad *Bufo marinus* L. were made to the Virgin Islands, Egypt, and Mauritius.

During May 1938 C. P. Clausen, in charge of the Division of Foreign Parasite Introduction of the Bureau of Entomology and Plant Quarantine, visited the station for the purpose of reviewing the work now in progress and to develop plans for future parasite introductions.

PARASITES AND PREDATORS OF SUGARCANE INSECTS

The Amazon fly, a parasite of the sugarcane borer, was introduced from British Guiana.

The Amazon fly (*Metagonistylum minense* Towns.), a parasite of the sugarcane borer, was first introduced into Puerto Rico in 1935 by the Bureau of Entomology and Plant Quarantine but failed to become established. However, unfavorable dry weather existed during and after the period of liberation and it therefore seemed desirable to attempt another introduction of this fly. In order to defray the expenses of such an introduction the Puerto Rico Sugar Producers' Association appropriated $450, which was supplemented with $100 donated by the Fajardo Sugar Co. The experiment station provided the entomologist to collect a breeding stock of the fly and to supervise its introduction and colonization.

In August 1937 K. A. Bartlett, associate entomologist, made a trip to British Guiana where a breeding stock of the fly was obtained. Three shipments consisting of 110 adults and 606 puparia of the Amazon fly were made to Puerto Rico by air express.

Adult Amazon flies were liberated.

The laboratory rearing of this parasite was started in October and continued throughout the year. Excellent cooperation was received from a number of the sugar producers of the island who provided *Diatraea saccharalis* (F.) larvae for the rearing work; these producers in turn received adult Amazon flies for liberation on their properties. Liberations of 10,789 reared flies were thus made at Añasco, Arroyo, Fajardo, Guayama, and Santa Isabel. Figure 29 shows the type of cage found most useful in mating and liberating these flies.

Collections of sugarcane borers (*Diatraea saccharalis*) were made at Añasco and Santa Isabel some months after liberation of the Amazon flies and a small percentage of the borers were found to be parasitized by *Metagonistylum minense*. At Santa Isabel parasites were collected at a point some 3 miles distant from the liberation point. It appears that initial establishment of this parasite has been accomplished.

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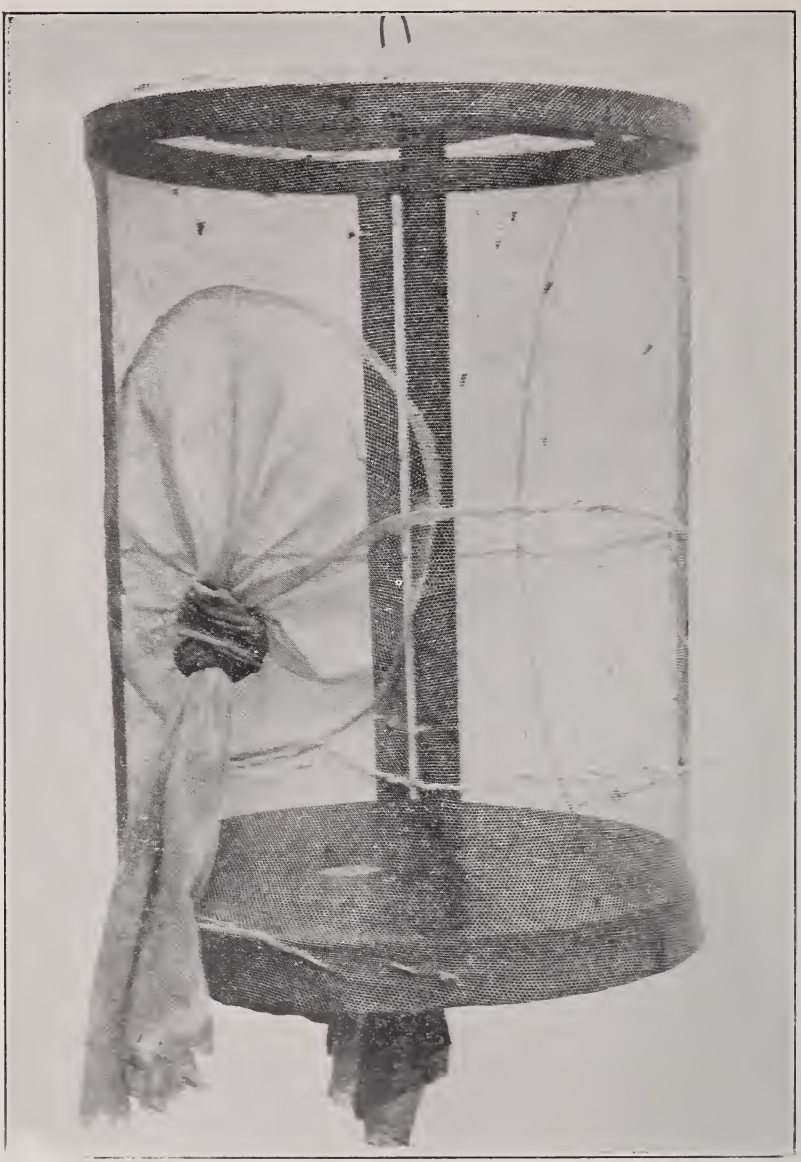

FIGURE 29.—Detail of a cage used for mating and storing Amazon flies prior to liberation against the sugarcane borer. The cage is 15 inches in diameter by 21 inches long and is covered with coarse bobbinett gathered and tied with a string at top and bottom. At left is shown a sleeve through which the flies are introduced into the cage.

Theresia claripalpis, a parasite of the sugarcane borer, was received from Trinidad.

In Trinidad *Theresia claripalpis* V. d W. plays an important part in the biological control of the sugarcane borer. In 1936 this parasite was introduced from Peru by the Bureau of Entomology and Plant

Quarantine. At that time 513 adults were liberated at Santa Isabel, but to date no recoveries have been effected.

During the past year two additional shipments of puparia of *Theresia claripalpis* were received through the cooperation of Alan Pickles, entomologist, Trinidad Department of Agriculture. A total of 118 puparia was received, 18 on May 10 and 100 on June 7. Rather than liberate directly the small numbers of the introduced parasites, they were reared in the insectary in order to make more extensive liberations throughout the cane-growing areas of the island.

The corn borer parasite, Chelonus annulipes, was introduced to parasitize the sugarcane moth borer.

During the past year a corn borer parasite, *Chelonus annulipes* Wesm., was introduced to parasitize the sugarcane moth borer; shipments were received from the laboratory of the Bureau of Entomology and Plant Quarantine at Toledo, Ohio. This braconid is a small wasp which was imported into the United States from Italy as a parasite of the European corn borer (*Pyrausta nubilalis* Hbn.). The sugarcane borer and the corn borer are closely related and quite similar in habits and life history. Both insects are internal stalk feeders in their larval stage and pass through nearly identical stages of development. The female *Chelonus* deposits its egg in the egg of its host. The host larva hatches normally and begins development, but when it has completed the fourth or fifth instar the parasite larva, which has been slowly consuming the body contents of its host, emerges and spins a cocoon from which the adult parasite later emerges. Under laboratory conditions it was possible to obtain oviposition by *Chelonus* in *Diatraea* eggs and to rear the parasites successfully through to the adult stage.

Of the total of 65,800 *Chelonus* adults shipped from Toledo, 43,459 arrived alive. Liberations were made throughout the cane-growing areas under various environmental conditions, a total of 43,249 adults being liberated in colonies of approximately 1,000 each.

Bassus stigmaterus was redistributed in the Fajardo district.

Two existing parasites, the tachinid *Lixophaga diatraeae* Towns. and the braconid *Bassus stigmaterus* (Cress.), frequently emerged from *Diatraea saccharalis* larvae which were being used in the laboratory for rearing of the Amazon fly. When adults of these two species were obtained they were redistributed in the field. Since *Lixophaga* is already present throughout the island the adults were released without regard to numbers or sites.

Bassus stigmaterus is a parasite introduced some years ago by H. E. Box from British Guiana; in the present studies it has been recovered only in the Añasco and Hormigueros Valley sections. In order to further the distribution of this parasite 52 adults were released at Fajardo in the vicinity of the experiment station of the Fajardo Sugar Co.

Adults of the Amazon fly and Lixophaga diatraeae were shipped to the continental United States.

Through arrangements effected by C. P. Clausen, two shipments of mated females of the Amazon fly (*Metagonistylum minense*) were made by air express from Puerto Rico to Florida and Louisiana. This material was used there as breeding stock from which to rear

parasite material for liberation in the sugarcane sections of these States.

The first shipment contained 39 females mated from April 25 to 30, inclusive, and was sent to J. W. Ingram of the Bureau of Entomology and Plant Quarantine at Houma, La., on May 3. The second shipment, 49 mated females, was sent to L. C. Scaramuzza at Fellsmere, Fla., on May 17. In addition to the Amazon fly, the Florida shipment also contained 25 adults and 32 puparia of the tachinid fly *Lixophaga diatraeae*, another parasite of the sugarcane borer.

A predator of the yellow aphid of sugarcane was introduced from Hawaii.

On January 6 a breeding stock of the coccinellid aphid predator, *Coelophora inaequalis* (Fabr.), was received from Q. C. Chock of the Board of Commissioners of Agriculture and Forestry of Hawaii. The shipment contained two cages of 197 adults each. In one cage all of the adults were dead while the other contained 102 living beetles. A second shipment of 200 beetles arrived on January 20, but unfortunately all were dead on arrival. This shipment was possibly routed by the northern air route across the United States where the exposure to low temperatures may have been fatal.

In Hawaii this ladybeetle attacks all species of aphids and is recorded by O. H. Swezey as an effective predator of young leafhoppers. Since its introduction into Puerto Rico it has fed voraciously in the laboratory on all species of aphids to which it has been exposed. It is hoped that it may become an effective predator of *Sipha flava* Forbes, the sugarcane aphid, which during the dry season causes considerable damage to young sugarcane, lemon grass, and other crops.

Recoveries were made following field liberations of Coelophora.

Coelophora inaequalis was successfully reared in the laboratory. During the year liberations were made of a total of 1,009 adults as follows: At Mayaguez, 257; Cabo Rojo, 230; and Villalba, 522. Field recoveries of small numbers of larval and adult stages of the beetles were made at Mayaguez and Villalba a few months after the liberations.

Native predators were abundant on yellow aphid infestation at Arroyo.

In January the results of a severe infestation of *Sipha flava* were noted on sugarcane at Arroyo. A young field of gran-cultura cane gave the appearance of having been burned as a result of the attack of this insect. However, at the time of observation the aphid population in the field had been considerably reduced by the activities of two predatory beetles, *Cycloneda sanguinea* L. var. *limbifer* Csy. and *Hyperaspis* sp.[7]

An entomogenous fungus was effective in the control of Sipha flava.

During the first week of February a period of humid weather resulted in a decided increase in the degree of control being effected by an entomogenous fungus attacking the yellow sugarcane aphid (*Sipha flava*) on lemon grass at the experiment station. While this fungus had been observed previously, it was of little importance during the dry weather. In a patch of lemon grass so closely planted as to give little opportunity for aeration, there resulted an almost 100-percent

[7] Determinations by E. A. Chapin, curator of insects, U. S. National Museum.

kill by this fungus; in adjacent patches of more widely spaced plantings of the same grass, however, the fungus did not bring the aphid infestation under control. Specimens of this fungus submitted to the Bureau of Plant Industry for determination were identified as *Acrostalagmus aphidum* Oud.[8]

A second predatory ladybeetle was introduced from Hawaii to help control Sipha flava.

Another predacious coccinellid, *Platyomus lividigaster* (Muls.), was introduced from Hawaii to help control *Sipha flava*. A shipment of 100 adults of this predator was received by air express on March 9. These beetles are aphid feeders and were originally imported into Hawaii from Australia. The material was assembled for shipment by Q. C. Chock of the Board of Commissioners of Agriculture and Forestry, Territory of Hawaii. The beetles were in excellent condition, and 92 were alive on arrival. A liberation of 72 adults was made at Lajas in March. Ten pairs of the beetles were retained for rearing purposes, but this predator was not successfully reared in the laboratory. In general the beetles did not appear to be particularly voracious on *Sipha flava*, but some feeding was observed in the laboratory.

PARASITES OF THE WEST INDIAN FRUITFLIES

Introduced parasite species was recovered from fruitfly puparia.

Numerous collections of jobo fruits (*Spondias* spp.), infested by the West Indian fruitfly (*Anastrepha mombinpraeoptans* Sein), were made during the year to ascertain whether or not introduced parasites of this fruitfly had become established. Two specimens of an introduced parasite species, *Spalangia philippinensis* Full., were recovered from a collection made at Juana Diaz on July 7. A. B. Gahan of the Bureau of Entomology and Plant Quarantine, who identified these specimens, wrote as follows:

> This *Spalangia* seems to be the species recently imported from Hawaii and which I have previously identified as *S. philippinensis*. I cannot be certain of the identification as I have not the type of *philippinensis* and it is impossible to be sure of any *Spalangia* on the basis of description.

The native parasite *Opius anastrephae* Vier. was prevalent in all of these collections. In addition, three other native parasite species, *Eucoila* sp., *Eucoila* (*Hexamerocera*) sp.,[9] and *Trichopria* sp.,[10] were reared.

Collections of *Anastrepha suspensa* Loew. infesting pomarrosa (*Eugenia jambos*) and guava (*Psidium guajava*) showed the presence of five native parasite species, *Pachycrepoideus dubius* Ashm., Encyrtidae gen. and sp.,[11] *Phaenopria* sp., *Ashmeadopria* sp.,[12] and *Eucoila* sp.[13]

Dirhinus giffardii, a fruitfly pupal parasite, was liberated throughout the island.

Rearing was continued of *Dirhinus giffardii* Silv., a pupal parasite of fruitflies introduced from Hawaii during the previous year. This

[8] Determination by Vera K. Charles of the Bureau of Plant Industry.
[9] Determined by L. H. Weld, Bureau of Entomology and Plant Quarantine.
[10] Determined by C. F. W. Muesebeck, Bureau of Entomology and Plant Quarantine.
[11] Determined by A. B. Gahan, Bureau of Entomology and Plant Quarantine.
[12] Determined by C. F. W. Muesebeck, Bureau of Entomology and Plant Quarantine.
[13] Determined by L. H. Weld, Bureau of Entomology and Plant Quarantine.

parasite was readily reared in the laboratory on fruitfly puparia (*Anastrepha* spp.) and housefly puparia (*Musca domestica* L.); and under laboratory conditions puparia of the papaya fruitfly (*Toxotrypana curvicauda* Gerst.) were also successfully parasitized. Liberations of 4,140 adults of *D. giffardii* were made at 9 points throughout the island.

PARASITES AND PREDATORS OF SCALE INSECTS

Four natural enemies of bamboo scales are indigenous.

After numerous unsuccessful attempts to rear native parasites from *Asterolecanium bambusae*, only one minute wasp, a species of *Cheiloneurus*, of the family of Encyrtidae,[14] was recovered. This was from a collection of the scale on *Bambusa vulgaris* twigs from near San Germán. Another species of the same genus, *Cheiloneurus pulvinariae* Dozier, has been previously recorded from Puerto Rico as a hyperparasite of *Aphycus flavus* Howard that parasitizes a scale on sugarcane.

At various times during the year three species of ladybeetles native to Puerto Rico, *Delphastus* sp., *Scymnillodes* sp., and *Stethorus* sp.,[15] were observed feeding on scales on bamboo and other plants.

Chilocorus cacti was introduced from Texas and Louisiana to prey on bamboo scales.

Since so few natural enemies had been found attacking the bamboo scales in Puerto Rico, the station took every opportunity during the year to introduce, along with natural enemies of the scale pests of other plants, ladybeetles that would prey on these scales.

The finding by Atherton Lee, director of the station, of a few adults of the ladybeetle, *Chilocorus cacti* (L.), feeding on the bamboo scale in Jamaica during March 1937 was recorded in last year's report. This same species is known to feed on a number of scale insects in the southern part of Texas and Louisiana and to be most abundant there during the spring and early summer months. While traveling in these States during August, H. K. Plank, associate entomologist, was requested to secure the species if possible. The species was found, although not abundantly, and a small breeding stock was assembled for introduction into Puerto Rico.

Twenty adults of *Chilocorus cacti* (L.)[16] were collected in an abandoned citrus orchard near San Benito, Tex., and 35 on the dictyospermum scale on *Podocarpus* in New Orleans, La. A total of 12 beetles survived the journey to Mayaguez, where efforts were made during the following months to multiply them on various scales in laboratory and field cages prior to liberation. In this breeding work colonies of the predator in cloth cages were tried on bamboo infested with both scales, and on papaya plants bearing heavy infestations of the white peach scale (*Aulacaspis pentagona* Ckll.) and the gray papaya scale (*Pseudoparlatoria ostreata* Ckll). Both the adults and the larvae of *Chilocorus* fed readily on all these scales.

Chilocorus cacti was established on bamboo and papaya scales.

In cages considerable multiplication of *Chilocorus* took place. During April and May some adults were noted to live for nearly 2

[14] Determined by A. B. Gahan, Bureau of Entomology and Plant Quarantine.
[15] Determined by E. A. Chapin, curator of insects, U. S. National Museum.
[16] Determined by E. A. Chapin, curator of insects, U. S. National Museum.

months, and under these conditions they oviposited freely. In one cage on papaya in which 4 adults had been placed on April 15, there were noted 64 adults and numerous larvae and pupae on June 15, more than a fifteenfold increase in 2 months.

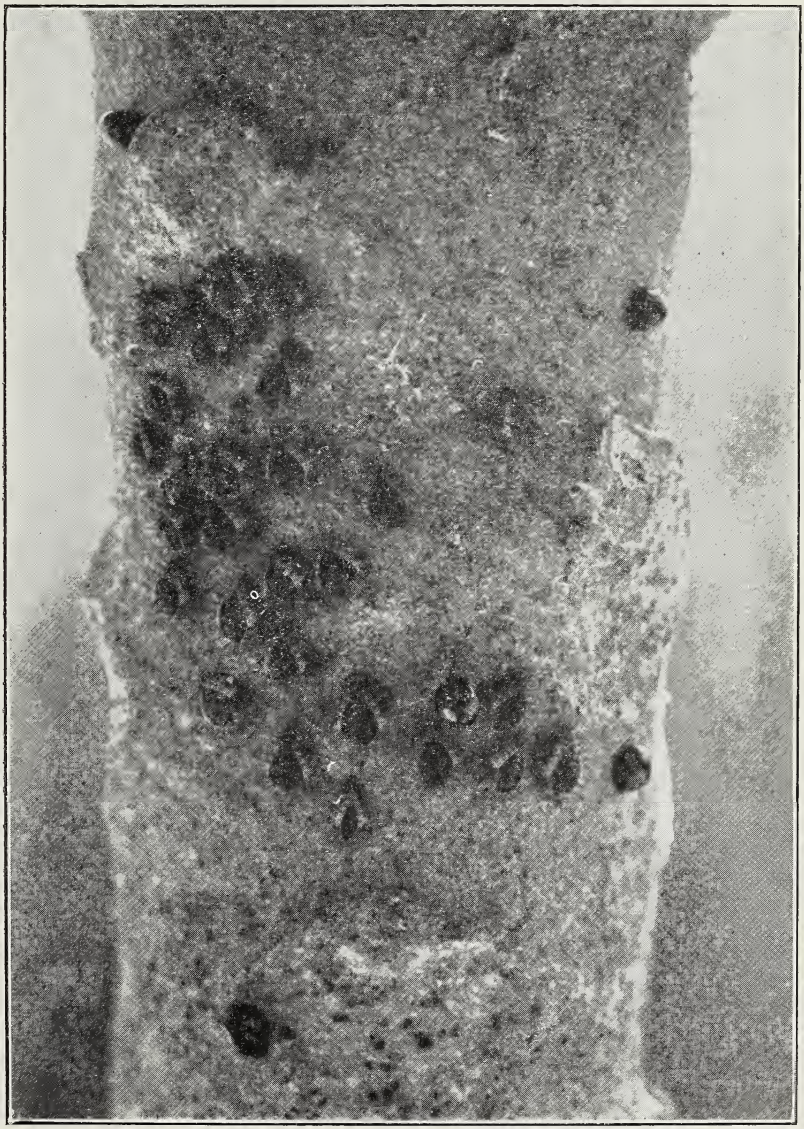

FIGURE 30.—Colony of pupae and adults of the introduced ladybeetle, *Chilocorus cacti*, on the gray scale (*Pseudoparlatoria ostreata*) on papaya on the Las Mesas property of the experiment station.

While the breeding work was being conducted, it was noted that some *Chilocorus* beetles pushed their eggs through the cheesecloth cover of some of the cages and that on hatching the larvae remained

on the outside. Initial colonization of this species in one clump of bamboo on the station grounds resulted in this way and through escapes during transfer and removal of breeding material.

Four adults placed in a cage loosely tied on a papaya plant on the Las Mesas property of the station on April 29 were the source of another colony that became established and by June 15 spread to other scale-infested papaya plants approximately 200 feet away from the original plant. At that time 100 or more beetles were counted on this plant and many more were later seen on plants nearby. A small group of pupae and adults on one of these plants is shown in figure 30.

On June 15 a colony of 100 adults, collected from breeding cages and from the above established colony, was liberated in a clump of bamboo near coconut palms and citrus trees on the Yaguez River at the experiment station in Mayaguez. By the end of June numerous larvae were noted feeding on the scale on the culms and some beetles were seen on the culms and the leaves.

Chilocorus cacti was further introduced from Cuba.

Through arrangements effected by C. P. Clausen, two species of ladybeetles, *Chilocorus cacti* and *Egius platycephalus* Muls.,[17] which prey on the bamboo scales, were received from the Department of Agriculture of Cuba during June. Both species were collected on bamboo in Habana by Angel R. Otero, entomologist of the Bureau of Plant Inspection, and transmitted by air express to San Juan, by Amadeo Lopez Castro, Secretary of Agriculture.

The first shipment, consisting of an estimated 1,086 adults of *Chilocorus cacti*, arrived on June 10. The next day 36 dead were counted, and an estimated total of 1,050 adults were liberated on bamboo scales as follows: At Bayamon, 700; at Vega Baja, 100; and at Barceloneta, 250.

In making the liberations, points were selected where the bamboo was growing contiguous to or near citrus and coconut trees so that the beetles would have the choice of a variety of host insects on which to establish and maintain themselves. In each instance the box containing the beetles to be liberated was pulled into the tops of the bamboo so that the beetles could escape and feed on the scale where lizards were less plentiful and less apt to molest the beneficial ladybeetles than on the culms. Some lizards were present at the time of liberation, but none was observed to feed on the beetles. When the colony at Bayamon was examined on June 26 some adults could be seen on culms in the clumps where liberations had been made.

Egius platycephalus ladybeetles were introduced from Cuba.

The shipment of *Egius platycephalus* arrived from Cuba on June 18. During the next 6 days an estimated total of 506 adults was liberated, 100 each at Gurabo, Bayamon, Guaynabo, and Dorado, and 106 at Arecibo. These liberations were made in the same kinds of habitats as those of *Chilocorus cacti*, but in different localities. Also the beetles were released on the leaves whenever possible so that the chances of their being molested by lizards would be reduced to a minimum.

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[17] Determined by E. A. Chapin, curator of insects, U. S. National Museum.

Predators on bamboo scales were collected in Trinidad, British Guiana, and Dutch Guiana.

During August, September, and October Dr. Bartlett made collections of predatory ladybeetles that attack the bamboo scales *Asterolecanium bambusae* and *A. miliaris* in St. Augustine, Trinidad, Georgetown, British Guiana, and Paramaribo, Dutch Guiana. All these collections were shipped to Puerto Rico by airplane. The shipment from Dutch Guiana unfortunately was delayed en route, and all of the material arrived dead. A record of the species shipped and the number surviving are shown in table 42.

TABLE 42.—*Predatory ladybeetles of the bamboo scales collected in Trinidad, Dutch Guiana, and British Guiana, and shipped to Puerto Rico during the fiscal year 1938*

Origin and date	Species [1]	Adult beetles	
		Shipped	Surviving
		Number	*Number*
Trinidad, Aug. 29	*Curinus* sp.	639	568
	Delphastus sp.	536	69
	Pentilia castanea Muls.	278	118
	Pentilia sp.[2]	24	
	Azya trinitatis Mars.	10	
	Cryptognatha nodiceps Mars.	11	
Dutch Guiana, Sept. 4 [3]	*Azya* sp. probably *trinitatis*	27	0
	Pentilia sp.	133	0
	do [2]	79	0
British Guiana, Sept. 24 and Oct. 2	*Azya trinitatis*	292	190
	Pentilia castanea	638	146
	Pentilia sp.[2]	82	49
Total		2,749	1,140

[1] Determined by E. A. Chapin, curator of insects, U. S. National Museum.
[2] Having a large red dot on each wing cover.
[3] Shipment delayed in transit.

The relative abundance of each species in the field was in proportion to the number recorded in table 42 as collected for shipment. The adults were most abundant on the leaves, feeding on *Asterolecanium miliaris* in spots of diffused sunlight, and only a few were present on the culms feeding on *A. bambusae*. However, larvae of the beetles were abundant on the leaves and were also seen feeding on *A. bambusae* on the culms. In general the infestation of *A. bambusae* was comparatively light.

Curinus sp. was liberated on bamboo scales at three places.

The 568 adults of the coccinellid *Curinus* sp. from Trinidad were liberated on bamboo scales as follows: On August 29 and 30, 368 adults were liberated in colonizing field cages at 4 points on the station grounds at Mayaguez; on August 31, 100 were set free on the south coast at Yauco; and 100 were liberated at Cidra. The beetles reproduced for about two generations in the field cages at the colonization points at Mayaguez, but soon decreased in numbers with the advent of fall and winter weather. Lizards were found in one instance to prey on the adults. The beetles were apparently unable to reproduce adequately under these conditions, for none could be found after May in the vicinity of any of these liberation points.

Delphastus sp. from Trinidad was liberated at Mayaguez.

The species of *Delphastus* introduced from Trinidad closely resembled that mentioned earlier in this report as being already established on bamboo and other diaspine scales in Puerto Rico. However, after a study of specimens of beetles from both sources, E. A. Chapin, curator of insects in the United States National Museum, stated that these two species were quite different.

The 69 *Delphastus* sp. received from Trinidad were liberated in two colonies on bamboo heavily infested with both bamboo scales on the station grounds at Mayaguez. One of these colonies had been increased in the laboratory and in field cages before liberation. A few adults have since been seen at the site of one of the original colonies. However, because of the close resemblance of the introduced *Delphastus* to the local species, it is difficult to determine to what extent the Trinidad species may have become established.

Cryptognatha nodiceps from Trinidad was liberated on bamboo scales.

Cryptognatha nodiceps was successfully established on coconut scales from an introduction by the Bureau of Entomology and Plant Quarantine in 1936. During the 1937 visit to Trinidad a few specimens that were observed attacking bamboo scales as occasional feeders were collected and sent along with the other species collected there. This species to date, however, apparently has failed to colonize on bamboo scales.

Azya trinitatis was first introduced by the Bureau of Entomology and Plant Quarantine in 1936 and is now well established on the coconut scale (*Aspidiotus destructor* Sign). During a trip to Trinidad and South America in September 1937, this species was observed feeding on bamboo scales. Collections of these ladybeetles sent to Puerto Rico at that time were liberated in two colonies on scale-infested bamboo on the station grounds at Mayaguez. Reproduction progressed satisfactorily on the bamboo scales at first, but the species has not successfully maintained itself. It appears that this species feeds only intermittently on bamboo scales in the absence of more preferred hosts.

Pentilia castanea was established on bamboo and papaya scales.

The adults of *Pentilia castanea* received from Trinidad and British Guiana in September and October were liberated in a clump of scale-infested bamboo at Mayaguez. Lizards were observed to eat a few of those beetles that moved about over the culms, but the majority of the beetles began to feed on the scale immediately. The remaining beetles from the above shipments were divided between two field cages on heavily infested culms for further multiplication. Attempts to colonize this ladybeetle by the above direct liberation and by transfer of adults and larvae to large cheesecloth bag cages placed over infested culms during the fall and winter were unsuccessful.

However, by the use of smaller bag cages placed on papaya plants infested with *Aulacaspis pentagona* and *Pseudoparlatoria ostreata*, and cages placed on bamboo infested with *Asterolecanium bambusae* and *A. miliaris*, it was possible to establish this ladybeetle on these scales. Reproduction took place to such an extent that additional field liberations could be started in January. It is of interest to note that in this work *Pentilia castanea* could not be reared on *Aulacaspis pentagona* infesting the giant milkweed (*Calotropis gigantea*), a fish-poison plant.

Pentilia castanea ladybeetles were redistributed to other localities.

From the colonies of *Pentilia castanea* bred up and established on bamboo and papaya scales on the station grounds, collections of adults were made and liberated on bamboo scales as follows: At Las Mesas 30, at Bayamon 500, and at Hormigueros 168. In addition 160 adults were liberated near Anasco on coconut scales, making a total of 858 in all which were released.

The colony of 30 adults liberated on papaya scales on Las Mesas on January 27 was noted to have increased to an estimated several hundred individuals by the middle of April and to have further increased and spread to many surrounding plants by June 15, when appreciable control of the scales on the original plants was already evident. A typical colony of this coccinellid on papaya scale is shown in figure 31.

The colony liberated on bamboo scales at Bayamon on April 14 multiplied rapidly; by June 11 some adults and an abundance of larvae could be seen on culms in other clumps of bamboo some distance from the original point of liberation.

The red-dotted species of Pentilia was established on bamboo scales.

Adults of the red-dotted species of *Pentilia* were received from Trinidad and British Guiana in September and October. In order to have a larger number for liberation, efforts were made at first to multiply them in field cages, but reproduction was slow. In the meantime two attempts had been made to establish this species on the bamboo scales by transferring some adults to bag cages over the end of heavily infested bamboo culms on the station grounds. On April 28 several beetles were discovered in one of these bag cages in which 10 adults had been placed on February 24. By June 2, these few adults had multiplied and spread over the rest of the culms in the same clump, attacking not only the scales on the culms but also those on the twigs and leaves.

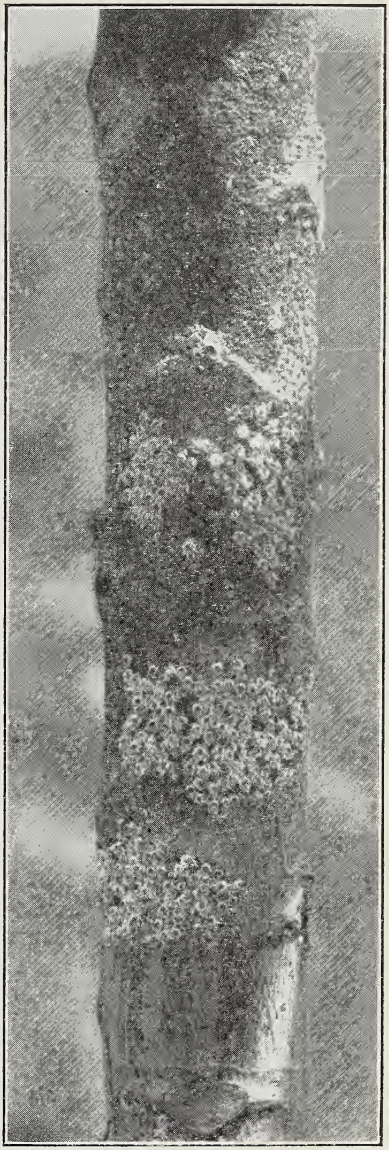

FIGURE 31.—Cluster of larvae and pupae of the introduced ladybeetle, *Pentilia castanea* Muls., colonized on the gray scale (*Pseudoparlatoria ostreata*) on trunk of papaya.

A predatory coccinellid which attacks bamboo scales was received from Martinique.

During a visit to Martinique, French West Indies, in late March Atherton Lee found a predacious coccinellid, *Curinus* sp.,[18] which was abundant and apparently effective there in the control of the bamboo scales *Asterolecanium bambusae* and *A. miliaris*.

Collections of this predatory beetle were made, and on March 26 an air express shipment of 433 beetles reached Puerto Rico; 427 were alive on arrival. A second shipment, brought personally by Director Lee, contained 125 adults, of which 120 were alive when they arrived on March 28. All living beetles, totaling 547, were liberated by K. A. Bartlett the day following arrival at Bayamon in a bamboo planting heavily infested with scales. Reproduction was noted to be progressing satisfactorily by the end of June.

The introduction of the bamboo-scale predators was handled by K. A. Bartlett, and except where otherwise indicated their rearing and colonization in Puerto Rico was conducted by H. K. Plank.

Imported ladybeetles attacking the coconut scale were redistributed.

A ladybeetle, *Azya trinitatis*, introduced from Trinidad in 1936 by the Bureau of Entomology and Plant Quarantine is now well established on the coconut scale (*Aspidiotus destructor* Sign.) in the vicinity of San Juan. Collections of these beetles were made from time to time and redistributed to aid in the dispersion and establishment of the species over the island. Colonies were thus liberated in scale-infested coconut groves at Guayanilla, Boqueron, and at La Fortaleza, San Juan. Although this last site is within a few miles of the point of the collection, the beetles had failed to spread in that direction. The barriers of the city and adverse winds have possibly been responsible, as spread in the opposite direction has been rapid.

A shipment of coconut scale predators was made to Florida.

On May 18 a shipment of several ladybeetle species that attack the coconut scale (*Aspidiotus destructor*) was made to Herbert Spencer of the Bureau of Entomology and Plant Quarantine at Orlando, Fla., for liberation against this scale. The beetles were collected in the vicinity of San Juan on May 17 and forwarded by air express to Miami. The shipment consisted of 800 *Azya trinitatis*, 800 *Delphastus* sp. (mottled brown) and 49 *Delphastus* sp. (black). The last 2 species are native, while *A. trinitatis* had been introduced from Trinidad in 1936. Dr. Spencer reported the beetles were in good condition on arrival, shortly after which he liberated 635 *A. trinitatis*, 738 *Delphastus* sp. (mottled brown), and 44 *Delphastus* sp. (black); the remainder were dead on arrival.

Pineapple mealybug parasite (Hambletonia pseudococcina) from Hawaii, became well established.

The pineapple mealybug parasite (*Hambletonia pseudococcina* Comp.), which was received from the Hawaiian Islands in 1937, was successfully reared in the laboratory in Carter cages. A total of 3,870 adults was reared for liberation as follows: Arecibo, 1,044; Corozal, 448; Lajas, 1,126; Mayaguez, 172; and Toa Alta, 1,080.

During February collections of pineapple plants infested with pineapple mealybug (*Pseudococcus brevipes* (Ckll.)) from Lajas showed

[18] Determined by E. A. Chapin, curator of insects, U. S. National Museum.

that *Hambletonia pseudococcina* was well established in that area. Collections made in the vicinity of the parasite-liberation point showed nearly every plant to contain some parasitized mealybugs. Adult parasites were seen in the fields, and on one plant brought into the laboratory 38 parasite puparia were found. The liberations which had been started at Lajas in March 1937 were discontinued 3 months later after 483 adults had been liberated. In March, this parasite was found to be established at Arecibo also, and further rearing work was discontinued. A number of *Hambletonia* adults obtained in other parasite-rearing work with the pineapple mealybug have been recovered from time to time and are being redistributed to aid in the dispersion of this beneficial insect.

Anagyrus coccidivorus, another introduced parasite of the pineapple mealybug, was liberated.

Anagyrus coccidivorus Dozier, the pineapple mealybug parasite recently imported from Hawaii, was also reared by means of Carter cages. Liberations of 4,272 adults, 1,856 males and 2,416 females, were made at Arecibo and Lajas during the year.

BIOLOGICAL CONTROL OF DUNG-BREEDING INSECTS

Adults of the horn fly parasite were liberated.

A number of inimical insects breed and pass their larval stages in dung. Two such species, the housefly (*Musca domestica*) and the horn fly (*Haematobia irritans* (L.)), are common pests in this island.

The pupal parasite *Spalangia philippinensis* which attacks the puparia of the horn fly and other dipterous puparia, was recorded in the last annual report as an introduction from the Hawaiian Islands. During the year 2,408 adults of this parasite were reared and liberated. A recovery of this species was made from fruitfly puparia (*Anastrepha mombinpraeoptans*) collected at Juana Diaz in July.

A dung-rolling beetle, Canthon pilularius, was received from Texas.

Two shipments of the dung beetle (*Canthon pilularius* (L.)) introduced to aid in the control of the horn fly of cattle were received from D. C. Parman, Bureau of Entomology and Plant Quarantine, Uvalde, Tex. A total of 9,548 adult beetles were received of which 4,952 reached Puerto Rico alive, Previous introductions of these beetles had been made by the Bureau in 1936. These beetles break the dung clumps into balls which they bury in the ground as food for their young and thus reduce the breeding places available for the horn fly.

The beetles were retained in the laboratory for a few days before liberation. Adult beetles of *Canthon pilularius* totaling 4,929 were liberated as follows: Arroyo, 925; Salinas, 1,851; Fajardo, 853; Penuelas, 588; and Ponce, 712.

A parasite new to Puerto Rico was reared from housefly puparia.

A hymenopterous parasite (*Muscidifurax raptor* Gir. and Sanders) [19] was reared from a puparium of *Musca domestica* collected at Hormigueros on June 21, 1937. This is the first record of this species from Puerto Rico.

[19] Determined by A. B. Gahan, Bureau of Entomology and Plant Quarantine.

PARASITES OF THE BEAN POD BORER

A new parasite of pod borers was introduced into Puerto Rico.

Two shipments of *Phanerotoma planifrons* (Nees), a parasite of the lima bean pod borer (*Etiella zinckenella* Treit.), were received from Moorestown, N. J., through cooperation with the Bureau of Entomology and Plant Quarantine. This material originated in France and was shipped to the United States in the cocoon stage, where it was reared and shipped to Puerto Rico in the adult stage.

The material reached Puerto Rico in excellent condition; the first shipment of 3,000 adults received on June 26 contained 126 dead, while the second shipment of 2,000 received June 29 contained only 52 dead. In order to insure mating before release, these parasites were retained for a few days in large laboratory cages, during which period some mortality took place. Liberations of *Phanerotoma planifrons* were made as follows: Arecibo 658, Barceloneta 1,000, Aguada 992, and Guanica 692.

Pod borers and bean leaf feeders were collected at Isabela.

During June 1936 an imported parasite, *Macrocentrus ancylivorus* Rohwer, was liberated at Isabela by the Bureau of Entomology and Plant Quarantine. In order to determine whether this parasite had become established, a collection of pod borers (*Etiella zinckenella*) in green beans and pigeon peas and a collection of leaf feeders (*Hedyelepta* (*Lamprosema*) *indicata* F.) on beans were made at Isabela on June 26, 1937. While no evidence of the imported species was found, a number of native parasites was reared from the material collected. Specimens of *Heterospilus etiellae* Rohwer, a parasite of the lima bean pod borer, were quite common. Two specimens of a dipterous parasite (*Agrophylax* sp.),[20] apparently new, were also reared from this material.

The leaf feeders were found to be parasitized by two native species, *Chrysocharis* sp.[21] and *Apantales* sp.[22]

MISCELLANEOUS

Rearing and liberation of thrips parasite were discontinued.

A thrips parasite (*Dasyscapus parvipennis* Gahan) was introduced by the Bureau of Entomology and Plant Quarantine from the Gold Coast, Africa, via Trinidad, in 1936, and 33 generations have been reared since then. A total of 29,457 puparia was reared during the fiscal year 1938. This parasite was successfully reared in the laboratory on the red-banded thrips (*Selenothrips rubrocinctus* (Giard.)) and on the onion thrips (*Thrips tabaci* Lind.).

After extensive and voluminous liberations of this parasite over the island recoveries have been confined to the first generation after release. Observations in Trinidad, where the parasite has been reared and liberated extensively since 1936, have not shown promise of any effective control of thrips. It is felt that the parasite is not able to maintain itself sufficiently under Puerto Rican conditions to be of benefit in the control of thrips, and further breeding work has been discontinued. Details of the rearing and liberations which have been made of this parasite are given in a manuscript that has been prepared for publication.

[20] Determined by D. G. Hall, Bureau of Entomology and Plant Quarantine.
[21] Determined by A. B. Gahan, Bureau of Entomology and Plant Quarantine.
[22] Determined by C. F. W. Muesebeck, Bureau of Entomology and Plant Quarantine.

Native predacious earwig was found feeding on banana corm weevil.

In 1935 a predatory beetle (*Plaesius javanus* Er.) was introduced into Puerto Rico from Fiji by the Bureau of Entomology and Plant Quarantine to combat the banana corm weevil (*Cosmopolites sordidus* Germar). Collections were made at Juana Diaz in July 1937 to attempt to recover this beetle. Large numbers of banana and plantain corms were cut in the vicinity of the liberation point, but no evidence of the imported predators could be found.

During the examination of the corms an earwig (*Psalis americana* (Beauv.))[23] was frequently encountered in the weevil tunnels. As these earwigs fed voraciously on the banana corm weevil when placed in a glass vial with them, this species is apparently predacious on larvae of that weevil.

Shipments of Bufo marinus were made to Egypt, Mauritius, and the Virgin Islands.

At the request of M. Kamal, entomologist, Cotton Research Board, Giza, Egypt, a shipment of 75 toads, *Bufo marinus*, was made to Egypt on July 29, 1937. A previous shipment was made to Dr. Kamal in 1936, but the toads apparently failed to become established at that time. The second shipment of toads was reported to have arrived in excellent condition with no mortality.

A collection of 71 toads was made about the experiment station grounds on October 21. These toads were taken by R. A. Nichols, horticulturist, to St. Thomas, V. I., for liberation there.

A shipment of 114 toads was made to England on November 5 for transshipment to Mauritius. These toads were requested by W. R. Thompson of the Imperial Institute of Entomology and were transshipped by him to Mauritius. The toads arrived in England with no mortality. It is of interest to note that the toads were hard to find at this time. A few days of dry weather were experienced just previous to collection and increased the difficulty with which the collection was made.

Except where otherwise indicated the biological-control activities of insect pests have been under the direction of K. A. Bartlett, associate entomologist. H. K. Plank, associate entomologist, supervised these projects while Dr. Bartlett was on leave during May and June.

ENTOMOLOGICAL INVESTIGATIONS

INVESTIGATIONS OF THE POWDER-POST BEETLE IN BAMBOO

In previous reports attention was directed to the destructive work of the bamboo powder-post beetle (*Dinoderus minutus* Fabr.) and its interference with the utilization of bamboo wood. Details were given of tests to show the relative susceptibility of the common species of bamboo (*Bambusa vulgaris*) and of five other species introduced by the station. Details were also given of an experiment in which it was found that immersing the culms in water for 8 weeks greatly reduced their susceptibility to beetle attack. The investigation of methods by which the beetles might further be controlled was continued during the present year with particular emphasis on the impregnation of the wood with poisons or deterrent chemicals.

[23] Determined by A. B. Gurney, Bureau of Entomology and Plant Quarantine.

Bamboo culms were treated with chemicals by the sap-stream method.

At the suggestion and through the cooperation of F. C. Craighead, in charge of Forest Insect Investigations of the Bureau of Entomology and Plant Quarantine, use was made of the natural forces of transpiration to carry chemical solutions in the sap stream to all parts of the culm. As in similar methods now employed to poison small trees, living culms were cut off and their bases immediately placed in receptacles containing a water solution of the chemical to be tested.

During May and June 1937, eight culms in each of five clumps of *Bambusa vulgaris*, the most borer-susceptible species of bamboo available, were used to test the effectiveness of five chemicals that might thus be employed to control the powder-post beetle. The culms were well established in clay soil on the station grounds at Mayaguez, where growing conditions varied from those on a river bank to those on a dry hilltop. The culms were selected for uniform size, and their age was as near 1 year as could be judged by experienced bamboo propagators. One culm in each of the five clumps was used for each of the treatments shown in table 43.

With the exception of the zinc meta-arsenite, which was used as received, all the chemicals mentioned in table 43 were dissolved in distilled water. Zinc chloride was dissolved at the rate of 226.8 grams, or ½ pound, per liter and ammonium bifluoride to the same molar, or gram-molecular, concentration. The solutions of the remaining chemicals were almost saturated, that of copper sulfate being nearly equal to the molar concentration of the zinc chloride and those of borax and zinc meta-arsenite each having a molar concentration of about 6.45 percent as much.

The chemicals in solution were applied through the bases of the upright culms.

All solutions, as well as the distilled water, were used at the rate of 1 liter per cubic foot of total volume, including both wood and hollow portions, of the culm to which applied. In the absence of exact dimensions of each culm, this cubical content was estimated from the circumference of the lowest internode in the culm by interpolation from measurements of other previously harvested culms of the same species and approximate age. The average total cubical content of the five culms used for each treatment, calculated from actual measurements at the time the culms were taken from their clumps, is shown in the fifth column in table 43.

In applying the chemical solutions and distilled water, the culm was sawed off near the ground and the cut end immediately placed in a container holding the solution to be tested. The culm with all the side branches on it was kept upright in the clump by tying it to adjacent uncut culms.

Rubber bags were the best containers for solutions applied by the sap-stream method.

In treating the culms in the first two clumps, namely, V and W, glass battery jars that measured 6½ inches in diameter by 9 inches tall were used to hold the solutions; roofing-paper collars in the form of a cone sealed around the culms with surgical tape covered the top of the jars against evaporation and the entrance of water from rain. A typical employment of this method is shown in figure 32.

TABLE 43.—*List of treatments, concentrations and amounts of solutions absorbed, and results in experiment to control the powder-post beetle with chemicals applied by the sap-stream method through the base of Bambusa vulgaris culms; experiment completed Sept. 7, 1937*

Treatment No.	Treatment[1]	Concentration of chemical in solution	Amount of chemical used in 1 liter of solution	Average total volume of culm	Solution absorbed per cubic foot of culm	Beetle attacks: Per 16 rings from— Clump V	Clump W	Clump X	Clump Y	Clump Z	Beetle attacks: Total per 80 rings	Control
		Moles	*Grams*	*Cubic feet*	*Liters*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Percent*
1	Untreated check; left uncut until all other culms were harvested, then tested green.			0.618		266	53	159	465	88	1,031	0.00
2	Cut off and left standing without any further treatment.			.409		5	51	19	3	9	87	91.56
3	Cut and treated through base with— Distilled water			.693	1.255	14	74	23	56	61	228	77.89
4	A commercial grade of borax	0.1074	41.04	.673	1.244	52	6	61	11	126	256	75.17
5	A commercial wood preservative said to contain 3 percent zinc meta-arsenite.	[2].1074	[2]30.00	.782	1.102	8	23	10	5	54	100	90.30
6	Commercial copper sulfate	1.3344	333.21	.814	1.186	17	4	4	89	6	120	88.36
7	A technical, white, granulated grade of zinc chloride.	1.6641	226.80	.737	1.229	35	60	39	4	92	230	77.69
8	A technical, purified grade of acid ammonium bifluoride.	1.6641	94.94	.698	1.252	6	32	65	3	7	113	89.04
	Total					403	303	380	636	443	2,165	

[1] All treatments applied to separate culms in each of 5 clumps.

[2] Calculated from manufacturer's statement.

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FIGURE 32.—Battery jars used to hold solutions of chemicals applied to bamboo culms by the sap-stream method in the experimental control of the powder-post beetle. When the culm was properly anchored, the roofing-paper cone, sealed about the culm with surgical tape and held together with paper clips, permitted twisting and swaying of the culm by the wind and at the same time effectively closed the top of the jar against evaporation and entrance of water from rain. These containers were not so serviceable as the rubber bags shown in figure 33.

Because ammonium bifluoride attacks glass, the jar holding this solution had to be coated on the inside with paraffin and the bottom protected from abrasion by a piece of wood. This procedure and the difficulty of always maintaining a perfect seal over the top of the jar

FIGURE 33.—Rubber bags made from sections of automobile tire inner tubing used to hold solutions of chemicals applied to bamboo culms by the sap-stream method. The bottom of the bag was closed with cement and wire; the top was held to the culm by means of a wire tightened immediately above a node and sealed with surgical tape. As the solution was absorbed the lower part of the bag was drawn up and held in place by a heavy rubber band.

was avoided in later treatments by using rubber bags, shown in figure 33, made of sections of discarded inner tubes from automobile tires in place of the jars. Being pliable and elastic, a container of this type was

found to have the additional advantage of being quickly attached and easily sealed to the culm, requiring much less anchoring of the base of the culm to prevent loss of solution, and permitting absorption within the capacity of the culm of all but a few drops of the dosage of solution applied.

Most of the solutions were readily absorbed.

In spite of the fact that the actual dosage exceeded by approximately 10 to 25 percent the planned dosage of 1 liter of solution per cubic foot of culm, all of the solutions were absorbed by individual culms in at most about a week, some within 24 hours, after being administered. The average amount of each solution absorbed per cubic foot by the five culms in each treatment is shown in the sixth column in table 43.

On the average, the zinc meta-arsenite solution, treatment 5, which was of low molar concentration, was absorbed more slowly and in less amount per cubic foot of culm than any of the other solutions. The borax solution, treatment 4, also of low molar concentration, was likewise slow in being absorbed, but about as much of this was absorbed per cubic foot as of either distilled water alone or ammonium bifluoride, the last solution having one of the highest molar concentrations used. It was apparent that the molar concentration of a solution had little if anything to do with the amount of such solution absorbed or the time in which it was absorbed.

Clear, dry weather increased absorption.

When the solutions were being applied to the culms in clumps V and W, that is, from May 5 to 13, there was little rainfall until the last day, and in addition the weather throughout was mostly clear and windy. It was noted that every one of the solutions was almost entirely absorbed within about 24 hours, an outstanding exception being the zinc meta-arsenite solution, treatment 5, of which in one instance over 15 percent of the dosage remained at the end of 195.5 hours. On the other hand, all of the 0.845 liter of ammonium bifluoride solution, treatment 8, applied in clump V was absorbed in less than 6 hours.

The weather prevailing when the culms in the remaining three clumps were being treated, from May 13 to June 24, was considerably more cloudy and rainy, and consequently less evaporation through the leaves took place before they ceased to function. The result was that under these wet conditions the absorption time of all of the solutions, including distilled water, almost doubled; the time required for the culm in clump Z to take up all of the borax solution, treatment 4, was 238 hours, and the minimum for ammonium bifluoride, treatment 8, was 23.75 hours.

It was evident throughout the experiment that both the amount and the speed of absorption were increased when clear weather with some air movement followed immediately after the solutions were applied.

Comparison with bamboo cured in the clump was provided.

In order to allow as thorough a distribution as possible of the chemical, the culms were left standing in an upright position in the various clumps for an average of about 26 days from the beginning of the treatments. At the end of this period, about which time the

leaves had started to fall, the untreated check culm, treatment 1, was cut and harvested together with the culms representing the other seven treatments in each clump. In other words, the culm representing treatment 1, which had been left growing, was cut and used green, i. e., without drying or other treatment, whereas all the other seven culms had been cut and left standing in the clump from the time the various treatments were applied. By following this procedure a green culm was provided in each clump for comparison not only with the culms treated with water and chemicals, but also with a culm that had been cut and dried, or cured in the clump for 26 days but otherwise untreated. Curing of freshly cut culms by dry storage has been shown in previous reports to lessen their susceptibility to powder-post beetle attack.

Test pieces used were taken from four positions in each culm.

Immediately after harvest, all eight culms of each clump were prepared for exposure to powder-post beetles in screened metal cages after the usual method employed in the species-susceptibility tests described in previous reports. However, in addition to using test pieces from the two adjacent internodes in the middle of each culm as heretofore, test pieces were taken from two more internodes, one at each extremity of the culm, which made four internodes in each culm from which test pieces were used in this experiment. This was done not only to reveal the average effect of a treatment as might be shown by using the middle internodes, but also to reveal the effect of any possible concentration of a chemical, or the reverse, in the extremities of the culms.

All treatments were well replicated.

The test pieces used in this experiment were in the usual form of rings three-fourths of an inch wide, and 4 such rings were sawed from each of the 4 internode positions just described. Since 8 culms were used in each clump there were thus 128 rings per clump, or a total of 640 rings from the 5 clumps. As the clumps were harvested at different times, the 128 rings from each clump were randomized in 2 cages, half in each cage, in such a way that each of the 8 treatments and each of the 4 internode positions were represented twice and the corresponding rings equally exposed to beetle attack in each cage. Four hundred field-collected powder-post beetles were then liberated in each cage and allowed to attack the test pieces for 1 month, at the end of which time the beetle attacks on each ring were counted and recorded.

Curing in the clump gave best beetle control.

In the last seven columns of table 43 is summarized by treatments and clumps the number of beetle attacks found on the rings from all internode positions in both sets of cages.

A statistical analysis of the beetle-attack data for table 43 showed that the powder-post beetle control produced by the various treatments varied in a highly significant way. On the basis of standard error, the difference in the number of attacks resulting from any two treatments would have to be 122 to indicate that the difference in control produced was significant, or show odds of 19 to 1 that the difference was due to causes other than chance, and 161 to indicate high significance, or odds of 99 to 1.

All treatments were highly significantly superior to the untreated check, or freshly cut, green culms. The treatment in which the culms were allowed to dry or cure in the clump for 26 days resulted in better control, 91.56 percent, than that produced by any other treatment applied in the experiment. However, the control effected by clump curing was not significantly superior to that of the zinc meta-arsenite, ammonium bifluoride, and copper sulfate treatments; nor were there any significant differences among the zinc chloride, borax, and distilled-water treatments. Clump curing and zinc meta-arsenite were significantly superior to the zinc chloride, borax, and distilled-water treatments, but in addition to the untreated check, copper sulfate and ammonium bifluoride were significantly superior to borax only.

Compared with clump curing none of chemical treatments were effective.

The freshly cut green culms served as an effective check for those culms receiving clump curing alone. However, since the culms treated with chemicals and distilled water were subjected to much the same type of clump curing as those subjected to clump curing alone, treatment 2, the latter treatment might be considered as the logical check for the distilled water and chemical treatments. With clump curing as the check, it will be noted from table 43 that the culm test pieces treated with chemicals and distilled water were more severely attacked by the powder-post beetles than were those from the check culms which received clump curing only.

Characteristic color changes that took place in the culms treated with copper sulfate, ammonium bifluoride, and to a lesser extent, zinc meta-arsenite indicated that these chemicals had penetrated to the tops of the culms. Since at least some of the chemicals appeared to be well distributed in the treated culms the results of this experiment indicate that from the practical standpoint there was nothing to be gained by the chemical treatments.

Copper sulfate colored the wood green.

Some of the chemicals changed the color of the culm, the most conspicuous change being that brought about by copper sulfate. In all the five culms treated with a solution of this chemical it was noted that the color of both the rind and the wood from the base to the top was changed to a chrome green. This color, which began to appear soon after the treatment was started and has persisted, might be considered objectionable in bamboo intended for use in the manufacture of certain articles. Ammonium bifluoride and, to a lesser extent, zinc meta-arsenite changed the color of the rind to a light fawn which if anything would enhance the beauty of the bamboo for furniture, picture frames, and other similar articles, depending on the taste of the user. Ammonium bifluoride seemed to be particularly effective in producing the light color; in culms treated with this chemical the color change was obvious soon after treatment, and shortly after harvest it was noted throughout the full length of the culms, where it has remained permanent.

Culms subjected to same treatment reacted differently to powder-post beetle.

Not only did the total number of beetle attacks on the ring-test pieces from any one clump differ from that of another, but the num-

ber of attacks observed on the rings from any one treatment also differed from that found on the rings from a similar treatment in another clump. The differences among clumps as well as the interaction between clumps and treatments in this respect were found by statistical analysis to be highly significant.

Bottom and middle internodes of treated culms were attacked less than the top.

It was mentioned on page 115 that rings were taken from internodes in four positions in each culm for testing the effectiveness of the various treatments in preventing beetle attack. Table 44 summarizes by treatments and internode positions the number of such attacks found on all the rings used in the experiment.

TABLE 44.—*Beetle attacks observed in test pieces from 4 specified positions in Bambusa vulgaris culms used in experiment to test chemical treatments applied by the sap-stream method; experiment completed Sept. 7, 1937*

Treatment No.	Treatment [1]	Beetle attacks				
		20 rings from internode position—				Total per 80 rings
		A, bottom	B, lower middle	C, upper middle	D, top	
		Number	*Number*	*Number*	*Number*	*Number*
1	None—culm tested green	195	218	322	296	1,031
2	Cut and cured in clump	44	17	15	11	87
3	Distilled water	65	43	63	57	228
4	Borax	132	53	31	40	256
5	Zinc meta-arsenite	1	29	30	40	100
6	Copper sulfate	4	18	15	83	120
7	Zinc chloride	2	61	51	116	230
8	Ammonium bifluoride	0	28	42	43	113
Total		443	467	569	686	2,165

[1] All treatments applied to separate culms in each of 5 clumps.

It is obvious from table 44 that on the whole the rings from the bottom and middle internodes of culms that received chemical treatments 5 to 8 inclusive, were attacked less by the beetle than the rings that came from the top internode of the same culms. Borax in treatment 4 produced the opposite response. In the absence of a chemical analysis of the wood, this would seem to indicate, except in the case of borax, a concentration and correspondingly increased effect of the chemicals in the lower parts of the culm and uneven distribution towards the top. That some of the chemicals were at least partly concentrated in the lower extremity of the culms was indicated early in the treatment period by changes in the color of these parts. The lower parts were the first to change color, usually to a lighter and in some cases a mottled shade of green, while the top retained its natural green color until near harvest and never assumed so deep a color as the base.

Bases of untreated culms tested green were attacked less than the tops.

The rings from the bottom and lower-middle internodes of the untreated culms were attacked less by the beetle than those from either the upper-middle or top internode portions in the same culms. However, in the culms that were clump-cured, treatment 2, and in

those that were treated with only distilled water, treatment 3, the rings from the basal internode received more attacks than those from any of the other three.

The first is a reversal and the last a confirmation of the results of previous experiments in which it was shown that the basal portion of bamboo culms was the most susceptible; and both point to a possible variation in nutrient content in different parts of the culm.

Differences in beetle attacks in different parts of the culm were found by statistical analysis to be highly significant, and show that the treatments as a whole were not equally effective throughout the entire length of the culm.

Two species of Lyctus beetles were found infesting bamboo wood.

A few specimens of two small, flat, brown beetles, *Lyctus caribeanus* Lesne and *L. curtulus* Casey,[24] slightly larger than *Dinoderus minutus*, were found in stored bamboo at Mayaguez. The bamboo was heavily infested with the powder-post beetle and these specimens were found with this beetle, some in the runways and some in the resulting powdered wood and fibers. Judging from the number found, possibly not more than 1 to every 500 of the powder-post beetle, it seemed that these *Lyctus* borers caused little injury to bamboo. Neither species has been previously recorded from Puerto Rico.

Two species of moth larvae caused little damage to bamboo foliage.

Adults of two species of moth larvae previously unrecorded as attacking bamboo in Puerto Rico were found to be *Epitomiptera orneodalis* (Guen.) and *Perichares corydon* Fabr.[25] The larvae of both species fed to such a small extent that both might be considered casual pests of bamboo.

Epitomiptera is a noctuid the larvae of which have already been reported as feeding on the leaves of papaya. The gray-green larvae, about 1 inch long, were found in November in loosely folded leaves of *Bambusa vulgaris* at Las Ochenta.

The larvae of *Perichares*, a hesperid, are often found in leaves of sugarcane held together by strands of silk. The light-green larvae were observed in November and December in the leaves of *Bambusa vulgaris* and of *Cephalostachyum pergracile* at the station.

One species of springtail was found associated with scale on bamboo.

Entomobrya cubensis Fols.,[26] a species of Collembola heretofore unrecorded from Puerto Rico, was reared from a collection of twigs of *Bambusa vulgaris* that were heavily infested with *Asterolecanium bambusae*. No damage to the bamboo by this springtail was noticeable.

INSECTS ATTACKING VANILLA

Survey of vanilla pests revealed four insects causing limited damage.

From November to February a number of vanilleries in the western and middle-southern sections of Puerto Rico were surveyed in company with C. F. Pennington, vanilla specialist, and A. G. Kevorkian, plant pathologist, of this station, and with vanilla specialists of the Puerto Rico Reconstruction Administration. In this survey four

[24] Determined by W. S. Fisher, Bureau of Entomology and Plant Quarantine.
[25] Determined by William Schaus, Bureau of Entomology and Plant Quarantine.
[26] Determined by H. B. Mills, Bureau of Entomology and Plant Quarantine.

insects and a snail were found injuring various parts of the vanilla vines.

A black weevil was associated with dying back of the tips of vanilla vines.

In four of the eight vanilleries visited, a withering and final blackening and shedding of the still unfolded leaves at the tip of some vines was found to be associated with small, round scars such as might result from the puncture of the epidermis by some insect. In places where

FIGURE 34.—Terminal portion of vanilla vine injured by a small black weevil (*Diorymerellus* sp. near *obliteratus* Champ.). Small sunken areas with an elliptical, water-soaked margin, shown on under side of unfolding leaf on shoot at left, are characteristic feeding punctures; some punctures can also be seen on the stem just below where the leaf is attached. Note tips of folded leaves beginning to die, and compare with uninjured shoot at right. (Natural size.)

the tip had died and dropped off, the vine sent out a new lateral shoot from the next node below. Most of the scars seemed to be old and these were usually sunk into the leaf or stem of the vine, but others, looking as if they had been freshly made, were flush with the surface, and the plant tissue surrounding them had a water-soaked appearance. A typical case is shown in figure 34.

In two of these four vanilleries, where the vines were about 2 years old, there was estimated to be from 1 to 3 percent of a dieback of the tips associated with the above injury. Here small black weevils of a species of *Diorymellus* near *obliteratus* Champ.[27] were found on the tips, leaves, and vines that bore this injury. In the other two vanilleries, where the plants were from 3 to 8 years old, similar feeding scars were found, but the amount of dieback of the tips was estimated to be only 0.5 percent, and no weevils were seen on the vines.

This weevil has been previously recorded from Puerto Rico on vanilla and also in the flowers of other orchids. When some of the weevils were caged in a cellophane bag on the terminal portion of a fresh vine, they were observed to feed readily on the tip, leaves, and stem and to cause the same kind of puncture scars as those found on injured vines in the field. However, in this experimental case, the still unfolded tips continued to grow and did not later abscise. Although it is possible that prolonged attack by the weevils on this part of the vanilla vine, particularly at the base of the unfolding leaf, may cause abscission of the tip, it is improbable that all of the dieback found was caused entirely by this insect.

A small leaf tyer attacked the tips of vanilla vines.

A number of injured and dying vanilla tips in a planting on the station grounds at Mayaguez were found to be infested with small yellow-green larvae that were feeding on the inside of the tied-up leaves. The small dark-brown moths that were reared from these larvae were found to be the torticid *Platynota rostrana* Walker, an insect that has a wide range of food plants.[28] The present is a new host record for this species in Puerto Rico, where it has been previously reported as feeding on rose leaves.

One species of earwig was found in vanilla tips.

In the above vanilla planting there were several injured tips that contained a few young earwigs of a species of *Doru*, probably *lineare* (Esch.).[29] While it was impossible to determine how much, if any, of the injury shown by these tips was caused by the earwig, it is probable that at least some was due to this insect. This species has been reported before from Puerto Rico in flowers of *Inga laurina* and has been taken in the flowers of *Erythrina* sp., but this is the first record on vanilla.

An aphid was found attacking the leaves of vanilla.

In one of the vanilleries surveyed the leaves of several 3-year-old vines were found attacked by *Cerataphis lataniae* (Boisd.). This aphid, which has been recorded before on vanilla, is a common pest of coconut and other palms in several parts of the island. The present infestation was slight in extent and not heavy on the plants attacked.

[27] Determined by L. L. Buchanan, Bureau of Entomology and Plant Quarantine.
[28] Determined by August Busck, Bureau of Entomology and Plant Quarantine.
[29] Determined by A. B. Gurney, Bureau of Entomology and Plant Quarantine.

That some natural control had taken place was shown by the fact that the aphids on some of the leaves were attacked by an unidentified species of white fungus, but the number of aphids killed by it was small. If the accumulation of sooty mold noted growing in the honeydew excreted by the aphids on the leaves and stems should develop on the vanilla beans it would no doubt cause some loss in quality.

Snails were found feeding on vanilla leaves.

In one vanillery near Villalba where the plants were 3 years old, a number of snails were seen on the middle-aged leaves of several vines. Some of the leaves had ragged edges and large, irregular scars near the middle. Specimens collected here were found to be *Thelidomus lima* Fér.[30] When placed in a cellophane bag on an undamaged vine three of these snails caused the same kind of scars on the leaves as was noted in the field. In one night they ate a shallow hole about seven-eighths of an inch in diameter in the upper surface of one leaf and at the end of 3 days scarred another leaf near the tip of the vine. It was apparent that this species is capable of causing considerable damage if allowed to propagate in large numbers. The extent of the damage where found, however, was not so great or the number of snails so large as to cause alarm or preclude the effectiveness of easily applied methods of control.

Tip borers lessened growth of bucare supports.

In all of the vanilleries visited much evidence was noted of insect injury to the bucare (*Erythrina berteroana*) used as living supports for the vines. In some cases the leaves were attacked by leaf worms, but the outstanding injury was that caused by the larvae of *Terastia meticulosalis* (Guenee).[31] These rose-colored larvae, about three-fourths of an inch long, bore into the tips of the new growth.

This common pest of *Erythrina* twigs in Puerto Rico was observed to do the greatest amount of damage to the new growth of bucare that was recently planted in open places, that is, where there was little or no shade from other trees or tall plants. The number of tips killed in some places was only about 25 percent, but in many vanilleries all the tips examined were infested, and the supports had failed to produce limbs of normal length and hence made poor shade for the vanilla. Some growers were abandoning the use of this *Erythrina* on account of the delay in support growth caused by this pest, for which there is at present no economical method of control.

Harold K. Plank, associate entomologist, has continued in charge of entomological investigations.

PLANT-DISEASE INVESTIGATIONS

PAPAYA BUNCHY TOP STUDIES

Protrusions were present on affected leaf petioles.

The studies of the bunchy top disease of the papaya (*Carica papaya*), begun during the last fiscal year, were continued with special reference to manifestations of the disease under varying conditions of soil and altitude and the testing of possible insect vectors.

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[30] Determined by Paul Bartsch, curator of mollusks, United States National Museum.
[31] Determined by Carl Heinrich, Bureau of Entomology and Plant Quarantine.

As pointed out in last year's report, the leaf petioles of the apical leaves of papaya plants affected with bunchy top are shorter and thicker than those of healthy trees and grow at a peculiar angle in relation to the stem. Further observations of diseased leaves have revealed numerous instances in which thickened, slightly dark-green protrusions were irregularly scattered on the petioles and on the veins. At times these areas were sufficiently numerous on the veins and petioles to give them a bumpy appearance.

Diseased leaf petioles contained calloused areas.

When 100 petioles from diseased trees were split longitudinally all were found to be almost solid instead of having a central cavity as is

FIGURE 35.—Longitudinally split papaya leaf petioles. *A* were from diseased plants and show the characteristic internal calloused areas and the pith proliferation typical of leaf petioles from plants affected by bunchy top. *B* was from a healthy plant and shows the hollow central cavity characteristic of petioles from normal plants.

common in petioles of healthy leaves. In addition to being almost solid, 83 of these 100 diseased petioles contained from 1 to approximately 50 internal calloused areas. These hardened areas were buff to tan in color and were scattered throughout the internal tissue. Those that were located directly beneath the epidermis caused the external protrusions and the bumpy appearance of the petioles. In figure 35 are shown a longitudinal section of a healthy petiole and sections of typical diseased petioles showing these calloused areas.

Calloused areas seemed correlated with insect punctures.

Central punctures found in the epidermis of a number of calloused areas suggested that these calluses were caused by insects. It was demonstrated in the longitudinal sections of such areas that the calloused regions had a large, light-tan-colored, internal protrusion which could be traced in a number of instances to a puncture in the epidermis.

Anatomical distortion resulted from calloused areas.

Microscopic examinations showed the internal anatomy of both the diseased petioles and the stems was severely altered by crowding of the corky, thick-walled cells of the calloused area. The vascular bundles, although not disrupted, were pushed out of their normal position and the component tissues were often disorganized by this abnormal growth, which undoubtedly interfered with normal translocation of food materials in the diseased plants.

Pith proliferation was associated with bunchy top.

Besides calloused areas, the diseased petioles were often found to contain a proliferation of pithy tissue that in advanced cases resulted in uniformly solid petioles whereas, as has been pointed out, the petioles of healthy plants are usually hollow.

Longitudinal sections were made of the apical portions of the stems of 30 diseased plants with the view to discovering any possible correlation between the solid condition of the petioles and the internal structure of the upper part of the diseased stem. The uppermost part of these plants was found to be solid about 6 inches farther from the tip than is common in healthy, mature plants. Twenty-five of the diseased plants were found to contain many calloused areas in this solid portion, while the other 5 contained no such areas. All the petioles were found to be solid on the 25 plants showing calloused areas in the stem tips. In other words, the presence of calloused areas in the apical portion of the stems of the diseased plants seemed to be associated with the occurrence of solid petioles.

Diseased papaya plants showed recovery.

During the dry season certain papaya plants that had been affected with bunchy top for some time produced new, apparently normal, leaves at the terminal buds. The petioles of these new leaves were longer and the leaf blades were larger, with a deeper green color than those of the diseased leaves appearing beneath them. This was so striking that the individual plants were easily recognized from a distance. However, a few weeks after the dry season ended these normal-appearing leaves finally showed typical bunchy top symptoms and succumbed to the disease. As a similar recovery and reappearance of the disease were noted at about the same time last year, such recoveries may be correlated with the winter dry season or some other closely related factor.

Lacebug did not transmit bunchy top disease.

The cotton lacebug (*Corythucha gossypii* (F.)), commonly found in colonies on the under side of leaves of papaya that have been in a diseased condition for some time, did not cause bunchy top symptoms to develop in potted healthy plants placed in cages with about 200 of these insects. Although lacebugs were present on most diseased plants, it was noted that the disease usually preceded their infestation. Because of some physiological change brought about by the disease, apparently, the diseased leaves were more suitable to their taste.

The southern green stinkbug did not transmit bunchy top.

The southern green stinkbug (*Nezara viridula* (L.)) found on both healthy and diseased papaya plants caused injury to petioles and the apical tips of plants when placed in cages with healthy plants, but

did not cause bunchy top. From 1 to 20 insects placed in cages for varying periods caused wilting and ultimate dying of the leaves because of the sucking of the juice from the petioles. Figure 36 shows typical results of this feeding.

FIGURE 36.—Papaya plant showing wilted terminal leaves as a result of southern green stinkbug injury. The speckled areas on the lower leaves are the result of lacebug feeding.

Plants 5 months old usually died after exposure for a period of 12 hours to two or more stinkbugs, especially when these were in the third or fourth instar. When the insects were allowed to feed on 5-month-old plants for a shorter period the leaves wilted and occasionally the apical tip of the plant died, after which healthy lateral shoots usually developed.

A new species of leafhopper was found to stunt papaya plants.

During the summer of 1937 J. H. Jensen, formerly plant pathologist and physiologist of the station, found what proved to be a new species of leafhopper feeding on the under surface of diseased and healthy papaya leaves. Specimens collected by Dr. Jensen were described by P. W. Omans, Bureau of Entomology and Plant Quarantine, who named the new species *Empoasca papayae* Oman. Thirty to fifty field-collected nymphs and adults of this insect were caged with young healthy plants and allowed to feed for 10 days. At the end of this period the plants appeared sickly and the insects were removed; control plants appeared normal. Although none of the sickly plants showed symptoms of bunchy top at this time, they remained in a stunted condition for about 4 weeks. Two months later symptoms resembling those of bunchy top appeared in the plants exposed to the insects but no such symptoms appeared in the control plants. Shortly afterwards a number of the plants succumbed to a root-rotting fungus and the experiment had to be abandoned.

Entomogenous fungi were found parasitizing papaya insects.

The entomogenous fungus *Entomophthora apiculata* Thax. was found parasitizing several leafhoppers, probably *Empoasca papayae*, on papaya leaves. A geometrid moth and a fly about the size of the common housefly were also found killed by the same fungus.

An imperfect fungus which seemed to be aggressive enough to serve as a partial control was found to have infected the cotton lacebugs (*Corythucha gossypii*) that were feeding on papaya plants.

VANILLA DISEASES

Twelve vanilleries were visited to determine extent of wilt or root rot.

During the past year a vanilla survey was conducted with C. F. Pennington, vanilla specialist of the station, in the course of which the principal vanilleries of the island were visited in order to determine the extent of vanilla wilt or root rot and other diseases which might be of significance in the production of vanilla.

Wilt, or root rot, is a diseased condition of the vanilla plant that destroys the cortex and stele of the roots. It subsequently causes the whole plant to wilt and eventually to die either by interfering with the food supply of the plant or through the production of toxic substances. Vanilla plantings on the station grounds have shown slightly over 10 percent wilt in the parent bed, and over 33 percent in a recently replanted site where vanilla had been abandoned a number of years ago because of this disease.

A total of 12 vanilleries were visited representing over 100 acres of vanilla that ranged from 4 months to 6 years or more in age. The location, acreage, age, and amount of disease found are shown in table 45. The condition of the plantings varied considerably, one vanillery, E, was completely abandoned, a few were receiving a minimum amount of care, and the rest were more or less carefully planned, with attention to location of site, terracing, mulching, and shade.

TABLE 45.—*Location, acreage, age, and estimated percentage of wilt and dieback in the vanilleries surveyed in February, March, and April 1938*

Vanillery	Location	Area planted	Age	Estimated proportion of—	
				Wilt	Dieback
		Acres		*Percent*	*Percent*
A	Las Marias Road	1½	2 years	1.0	3.0
B	do	2½	4 months	0	0
C	do	[1]2	2 years	20.0	1.0
D	do	2	5 months	0	1.0
E	Villalba	1	5–6 years	80.0–90.0	0
F	do	10	3 years	20.0–30.0	.5
G	do	3	1–2 years	0	0
H	do	50	2 months–8 years	10.0–15.0	.5
I	Morovis-Corozal Road	40	3 months–3 years	0	0
J	do	10	6 months–2 years	0	0
K	Ponce district	10	1–3 years	3.0	2.0
L	Adjuntas	8	7 months–1½ years	10.0	20.0

[1] 20 percent of this field stated to be attacked by wilt; replanted June 1937.

Seven of the twelve sites visited were affected by wilt.

Those plantings that were 6 months or less in age were free from wilt, whereas in all but three vanilleries containing plants 1 year old or older, the disease was present to some extent. The proportion of diseased plants ranged from less than 1 to as high as 90 percent. The estimated average of wilted plants noted in five vanilleries amounted to 22.3 percent. There was no correlation between amount of care and extent of disease present.

All but one of the isolations made from representative decaying roots from wilted plants collected at the various plantations yielded a species of the fungus *Fusarium*.

A dying back of growing tips was encountered.

A diseased condition of the growing tips of vanilla was the only other disease noted in the survey. This condition was found in seven of the vanilleries visited. The disease involves the two or three terminally developing nodes and the leaves accompanying them. The first indication of the disease appears at the apical tip of the fully developed but partially unrolled terminal leaf. That portion of the leaf which is normally slightly recurved becomes acutely curved and turns brown and watery. Within 24 hours the whole leaf becomes discolored and necrotic. Moreover, the portion of the stem above this leaf becomes involved and eventually dies, leaving a brittle, shriveled terminal portion consisting of the apical end of the vine, two or three nodes, and a similar number of leaves. This disease occurs chiefly during the dry season and frequently accompanies root rot or wilt.

In several localities, markings that appeared to be insect punctures were found associated with this disease, whereas in other localities no such injuries were noted. Microscopic examination and culturing of the necrotic areas did not reveal the presence of micro-organisms.

Dieback was of minor significance as compared with wilt.

Although dieback was found to affect as much as 20 percent of some plantings, the damage apparently is only of temporary importance, in that growth is retarded only until a new lateral shoot develops in the axil of the leaf at the first sound node below the shriveled

tip. Compared with wilt, which involves the whole plant and eventually causes its death, the present dieback disease is of minor significance.

SUGARCANE DISEASES

Cooperative sugarcane-chlorosis studies were continued.

Two sugarcane-chlorosis experiments that were started in 1936 were continued during the year with the first-ratoon crop of variety B. H. 10 (12). These experiments consisted of a sulfur-quantity test and a manganese sulfate and sulfur test on Santa Isabel silty loam of high alkaline reaction. J. H. Jensen, formerly plant pathologist and physiologist of the station, initiated these tests and recorded the results of the plant-crop in the 1937 annual report.

These experiments were located in the Cortada division of Luce & Co., Santa Isabel, and were conducted on a cooperative basis between that organization and the station.

Soil reaction remained highly alkaline.

Soil samples were taken at the beginning and at the termination of the experiments both for the plant cane and the first-ratoon cane as well as at regular intervals during the growing period. However, the high alkaline condition of the soil persisted since at no time throughout the experimental period was the hydrogen-ion concentration of any plat less than 8.5. All pH determinations were made by J. O. Carrero, assistant chemist of the station.

Ratoon crop of cane was harvested in sulfur-quantity experiment.

The sulfur-quantity experiment was conducted to test the effect of different quantities of sulfur upon the yield of chlorotic B. H. 10 (12) sugarcane growing on Santa Isabel silty clay loam of a high alkaline reaction. The plant cane harvested during 1937 showed that there were no statistically significant changes in the tonnage of cane or of sugar per acre produced by the different treatments, nor were there any appreciable changes in the soil reaction. This report is concerned with the effects of sulfur on the yield of the first-ratoon crop.

Sulfur was applied in varying amounts to the plant cane on June 23, 1936, but the applications were not repeated for the ratoon cane. Fertilizer consisting of 640 pounds of ammonium sulfate, 128 pounds of superphosphate, and 32 pounds of potassium sulfate was applied to the ratoons in two applications on June 3 and July 20, 1937. The amounts of sulfur applied in the four treatments are shown in table 46, together with a summary of the yield data of the ratoon crop. The statistical analyses of these yield data are contained in table 47.

TABLE 46.—*Yield data of B. H. 10 (12) sugarcane sulfur-quantity test on Santa Isabel silty clay loam at Santa Isabel, 1937–38* [1]

Lot	Sulfur per acre	Juice analyses			Yields per acre	
		Brix	Sucrose	Purity	Cane	Sugar
	Pounds	*Degrees*	*Percent*	*Percent*	*Tons*	*Tons*
A	1,000	19.95	18.00	90.20	43.65	5.71
B	2,000	20.10	18.25	90.80	42.17	5.59
C	4,000	20.10	18.20	90.45	42.34	5.61
D	0	20.00	18.05	90.20	41.76	5.50

[1] Planned by Atherton Lee and J. H. Jensen. Laid out by J. H. Jensen, L. A. Gómez, M. S. Baker, and L. A. Roqué. Harvested by A. G. Kevorkian and L. A. Roqué. Planted Apr. 18, 1936; sulfur applied June 23, 1936; ratooned Mar. 29, 1937; ratoon crop fertilized June 3 and July 20, 1937; harvested Apr. 10, 1938; age at harvest, 12¼ months.

TABLE 47.—*Analyses of variance of yield data obtained in sulfur-quantity test with B. H. 10 (12) sugarcane on Santa Isabel silty clay loam at Santa Isabel, 1937–38*

Source of variance	Degrees of freedom	Mean squares				
		Juice analyses			Yields per acre	
		Brix	Sucrose	Purity	Cane	Sugar
		Degrees	*Percent*	*Percent*	*Tons*	*Tons*
Total	23	0.18	0.27	0.81	12.71	0.17
Replications	5	.58	.80	1.60	39.18	.50
Treatments	3	.07	.07	.47	4.00	.04
Error	15	.08	.14	.61	5.62	.08
F value for treatments [1]		.84	.48	.77	.71	.50

[1] *F* value of 3.29 is necessary to give odds of 19 to 1 that differences among treatments were due to some factor other than chance. Odds less than 19 to 1 considered not significant.

Sulfur applications gave no significant differences in yields.

Tables 46 and 47 show that in the sulfur-treated plats there was a slight trend towards improvement in the juice qualities, and increase in cane tonnage as well as sugar per acre. These differences were not statistically significant since for every yield criterion the error variance was greater than the treatment variance.

Ratoon cane was harvested in manganese sulfate and sulfur experiment.

As in the sulfur-quantity test this experiment was conducted with chlorotic-affected sugarcane at Cortada division of Luce & Co. Here also the treatments were not repeated for the first-ratoon cane.

The amounts of manganese sulfate and sulfur applied in the various treatments are shown in table 48, together with a summary of the yield data of the ratoon crop.

TABLE 48.—*Yield data of manganese sulfate and sulfur experiment with B. H. 10 (12) sugarcane on Santa Isabel silty clay loam at Santa Isabel, 1937–38* [1]

Lot	Treatment		Juice analyses			Yields per acre	
	Manganese sulfate per acre	Sulfur per acre	Brix	Sucrose	Purity	Cane	Sugar
	Pounds	*Pounds*	*Degrees*	*Percent*	*Percent*	*Tons*	*Tons*
A	200	0	20.50	18.65	91.01	42.47	5.78
B	200	1,000	20.42	18.58	91.01	42.47	5.76
C	0	1,000	20.42	18.68	91.51	44.14	6.02
D	0	0	20.50	18.61	90.81	42.99	5.84

[1] Planned by Atherton Lee and J. H. Jensen. Laid out by J. H. Jensen, L. A. Gómez, M. S. Baker, and L. A. Roqué. Harvested by A. G. Kevorkian and L. A. Roqué. Planted Apr. 18, 1936; sulfur applied June 23, 1936; ratooned Mar. 29, 1937; ratoon crop fertilized June 3 and July 20, 1937; harvested Apr. 10, 1938; age at harvest, 12¼ months.

Differences in mean yield were negligible.

The mean yields for the different treatments were closely similar for every yield criterion. The greatest difference was shown in cane tonnage, in which there was 1.67 tons difference between the highest and lowest yield, whereas the difference between the maximum and minimum sugar yield was only 0.26 ton. Table 49 contains the statistical analyses of these data.

TABLE 49.—*Analyses of variance of yield data obtained from manganese sulfate and sulfur experiment with B. H. 10 (12) sugarcane on Santa Isabel silty clay loam at Santa Isabel, 1937–38*

Source of variance	Degrees of freedom	Mean squares for—				
		Juice analyses			Yields per acre	
		Brix	Sucrose	Purity	Cane	Sugar
		Degrees	*Percent*	*Percent*	*Tons*	*Tons*
Total	23	0.26	0.29	0.62	7.32	0.09
Replications	5	1.02	1.16	1.22	21.88	.17
Treatments	3	.03	.03	.53	3.74	.09
Error	15	.05	.05	.43	3.19	.06
F value for treatments[1]		.60	.60	1.23	1.17	1.50

[1] *F* value of 3.29 is necessary to give odds of 19 to 1 that differences among treatments were due to some factor other than chance. Odds less than 19 to 1 considered not significant.

Costs of the treatment were greater than the values of increased sugar.

The analyses of the yield data (table 49) show that with no yield criterion was the treatment response statistically significant. In every case the odds were much less than 19 to 1 that the observed treatment differences were due to some factor other than chance.

The conclusions from the sulfur-quantity and this manganese sulfate and sulfur experiment harvest corroborate the results expressed in last year's report for the plant cane, indicating that the amount of the materials required to make any appreciable improvement in chlorosis and yields on soils of such high calcareous content would be so great that the applications would not be profitable.

Appreciation is expressed to Luce & Co. for their complete and effective cooperation in conducting the foregoing experiments.

PLANT-QUARANTINE SERVICE

The plant-quarantine house has been used extensively for official quarantine purposes. Many economic and ornamental plants new to Puerto Rico have been introduced by this station in an endeavor to establish additional high-value crops that may be adapted to the ecological conditions of the island.

A total of 162 introduced plants, representing 50 species, were held in the quarantine house for periods of 6 to 12 months in each case. These were first inspected, then held in quarantine for prescribed periods, and released upon orders from either the Insular or Federal quarantine officials. The facilities of the quarantine house are being used by other agencies of the Federal and Insular Governments.

Plant-disease investigations and administration of the plant-quarantine house have been carried on by Arthur G. Kevorkian.

CHEMISTRY INVESTIGATIONS

The chemistry division gave service to many agencies.

The investigations in chemistry conducted during the year were concerned with a study of some of the conditions surrounding the manufacture of byproducts of the sweet orange and a continuation of the analysis of local grasses and legumes with a view to their utilization as cattle feeds. In addition, many routine analyses were made

of soils and other materials, and consultations held with workers in other divisions of the experiment station, entities of the Federal and Insular Governments, and with groups of agriculturists.

Cheap oranges may be utilized in production of distinctive orange wine.

Throughout the coffee section of the island there are numbers of sweet orange trees bearing fruit of unusually fine flavor and juice content. Since the West Indian fruitfly (*Anastrepha mombinpraeoptans*) occurs in Puerto Rico and not in the continental United States there has been a quarantine prohibiting the shipment of oranges from the island to the continent. Recently, however, the quarantine has been lifted provided the fruits are subjected to specified low temperatures for a period of time found sufficient to kill the immature stages of the fruitfly. Because of the keen competition with oranges produced in Florida and California, shippers have hesitated to undertake the cost of such sterilization.

One of the possible methods of utilizing these oranges has seemed to be in the extraction and fermentation of the juice for making orange wine. Such wine as produced in the laboratory has a beautiful orange color and is somewhat comparable to sherry in character. Tourists visiting Mayaguez have shown interest in taking home such a distinctive product.

The utilization of the oranges in the production of this wine has seemed to be an outlet worthy of investigation.

Orange juice was low in sugar and high in acid.

Previous to running a preliminary fermentation test on several lots of oranges purchased on different days on the local market, analyses revealed that while the untreated juices varied greatly, they were uniformly low in sugar and high in citric acid. Fermentation of these juices yielded products correspondingly low in alcohol and high in citric acid. The results of these analyses are shown in table 50.

TABLE 50.—*Analysis of fresh and fermented juice from 5 lots of oranges purchased in the Mayaguez public market on different dates during the 1937–38 season*

Lot	Date samples obtained	Fresh juice			Fermented juice	
		Brix	Citric acid	Total sugars	Alcohol	Total sugars
		Degrees	*Grams per 100 milliliters*	*Grams per 100 milliliters*	*Percent*	*Grams per 100 milliliters*
A	Dec. 22, 1937	10.2	0.90	9.00	4.56	None.
B	Jan. 3, 1938	8.4	.73	7.48	3.92	Do.
C	Jan. 7, 1938	10.0	1.04	9.02	4.68	Do.
D	Jan. 18, 1938	11.1	1.27	10.10	5.16	Do.
E	Feb. 20, 1938	11.5	1.35	10.20	5.25	Do.

It was apparent from the foregoing, and as found in orange-fermentation studies elsewhere, that sugar would have to be added to the juice of local oranges in order to produce a wine equal to most commercial wines containing as much as 12 or 14 percent of alcohol.

Addition of sugar to orange juice increased alcohol and sugar in resulting wine.

Wine-grape juices are known to have a Brix reading that ranges from 22° to 26°, and in most cases their sugar content is high enough to produce an alcohol content of 12 to 15 percent and a low percentage of invert sugar in the fermented product. To observe the result of increasing the Brix reading by the addition of sugar before fermentation, enough sugar was added to several lots of orange juice to raise this reading to 22°. The alcohol content of the fermented product ranged from 11.80 to 12.80 percent and the sugar from 0.35 to 0.75 percent.

In a second set of trials in which the Brix reading of the orange juice was raised to 24°, the alcohol content of the fermented product ranged from 13 to 14 percent, while the content of invert sugar ranged from 1.80 to 2.30 percent, depending on the quantity of sugar added.

The above orange wines of low sugar content were unpalatable because of the relatively great amount of acid in them; the higher the sugar content the less noticeable was the degree of acidity, those wines with 2.25 percent or more of sugar possessing the best flavor.

Orange oil in extracted juice caused a pungent flavor in orange wine.

It was noted that all of the foregoing wines possessed a somewhat bitter flavor. In an effort to eliminate this, the juice was extracted from similar lots of oranges by three different methods and fermented separately. Method 1 was that employed to extract the juice used in the foregoing fermentation tests; the fruit was cut in two between the stem and apical ends and each half pressed onto the cone-shaped burr of an electrically driven juice extractor such as that commonly used at soda fountains. In method 2 the portion of the rind containing the oil cells was peeled off before cutting the orange in half and extracting the juice as just described. In method 3 the fruit was handled as in method 2, but the juice was squeezed out by means of an aluminum hand squeezer fastened to a table and having a handle by which considerable pressure was exerted on each fruit half.

After fermentation had stopped, a considerable difference in flavor was noted between the three lots of wine. That from method 1 had a strong, bitter taste in which the pungent flavor of orange oil could readily be detected. The wine from the oranges processed by method 2 also had a bitter flavor but was almost free from that of orange oil. The wine from the oranges processed by method 3 had the best flavor, being nearly free from bitter taste and possessing no flavor of orange oil.

Orange fruit pulp in extracted juice produced a bitter-flavored wine.

The test was repeated with identical lots of similar oranges, but after extraction by each method, the juice was strained through one thickness of ordinary cheesecloth before fermentation. This filtration removed all juice cells and other fruit pulp except very small particles of cellular material set free during extraction.

While some degree of bitterness was detected in the wine from all three lots of filtered juice and was especially noticeable in that from the lot extracted without peeling the fruit beforehand, the flavor of the other two lots was greatly improved. The wine from the juice that had been extracted from peeled oranges by means of the hand squeezer was most free from bitter taste.

In the two foregoing tests it was apparent that peeling the oranges to prevent the entrance of rind oil, extracting the juice with a press or squeezer, and filtering the juice to remove fruit pulp and cellular material all tended to improve the flavor of the resulting wine.

Fruit pods of the legume, Gliricidia sepium, were high in protein.

The leguminous tree, *Gliricidia sepium*, useful as a shade tree for coffee and vanilla, bears an abundance of long pods that are eaten avidly by dairy cattle. In order to gain some idea of the feeding value of these pods, a series of analyses was made of the empty pods, the shelled beans, and of the entire fruits. The fruits used for these analyses were harvested in three different stages of development. In the first stage the entire fruit was fresh and green and otherwise obviously undeveloped. In the second stage the fruits were still fresh and the pods pliable, but the pods had become somewhat leathery and the beans in them were well filled out to complete maturity. The fruits in the third stage were fully mature and had already dried on the tree before picking. The results of the analyses of each part in all three stages of development are shown in table 51.

TABLE 51.—*Principal feeding constituents of pods and beans of Gliricidia sepium at different stages of development on moist basis as harvested*

Part and stage of development	Proportion of full pod	Moisture	Dry matter	Crude fat	Crude protein N×6.25	Total sugar	Total ash
Empty pods:	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Green, undeveloped	88.91	70.02	29.98	0.06	2.24	0.51	0.93
Mature	85.24	64.34	35.66	.06	1.94	.47	1.06
Dry, mature	83.66	18.10	81.90	.35	4.04	.81	2.91
Beans only:							
Green, undeveloped	11.09	74.76	25.24	3.19	11.25	.47	1.21
Mature	14.76	66.18	33.82	7.83	15.42	.88	1.39
Dry, mature	16.34	24.88	75.12	15.36	35.07	1.14	3.16
Entire fruits:							
Green, undeveloped	100.00	70.55	29.45	.39	3.18	.51	.95
Mature	100.00	64.61	35.40	1.17	3.87	.60	1.11
Dry, mature	100.00	19.21	80.79	2.73	8.97	.86	2.95

All parts of the dry, mature fruits were found to be higher in fat, protein, and sugars than the same parts of the less mature fruits. As was to be expected, most of this nutrient value was found in the seeds or beans, which also were high in ash. However, a good proportion of protein was located in the pods, especially those that had dried before being harvested.

The foregoing investigations have been carried on by J. O. Carrero, assistant chemist.

COOPERATION WITH INSULAR GOVERNMENT

The Insular Legislature increased annual appropriation to $26,900.

In April 1937 the Legislature of Puerto Rico appropriated $18,000 from the Insular treasury to provide for cooperation of the Government of Puerto Rico with the Federal station in agronomic and processing investigations for the production of vanilla, spices, and perfumes. In the last session of the legislature an amendment to this act was passed and approved by the Governor on May 4, increasing the appropriation for cooperation with the experiment station to $26,900,

including an appropriation for the studies of bamboo utilization on small farms. This became effective July 1, 1938.

Coffee research continues in cooperation with the experiment station of the University of Puerto Rico.

The cooperative project on coffee research with the experiment station of the University of Puerto Rico, which was inaugurated in 1935, has continued throughout the year. Not only have cordial and pleasant relations existed with the personnel in coffee investigations but also with other members of the staff at Rio Piedras. Mutual exchange of propagating material has been made from time to time and mutual use of library facilities continued.

Pleasant relations of informal cooperation continued with the College of Agriculture and Mechanic Arts. The director of the station has continued to serve as a member of the faculty of the college.

COOPERATION WITH THE PUERTO RICO RECONSTRUCTION ADMINISTRATION

Sixty men were made available for bamboo and mango propagation.

The cooperation with the Puerto Rico Reconstruction Administration was continued during the year. Throughout 10 months of the year from 50 to 60 men were available for propagating new species of bamboo and new varieties of mangoes for the extension of these crops throughout the island. During the dry season, when planting was not advisable, a number of physical improvements were also made by such personnel from the Reconstruction Administration. Three acres of additional bench terraces and 1.48 acres of Mangum terraces were completed in Benet field at Las Mesas. A total of 11 acres was contour-canalled, including the general pasture and areas for bay-oil and forage-grass plantings.

An earth dam in the eastern valley to store three-fourths of an acre-foot of irrigation water was also constructed with labor furnished by the Reconstruction Administration and this dam also functions as another flood-control unit.

Five hundred and twenty meters of plantation road were constructed to reach bamboo and mango propagating areas to facilitate planting and future harvesting operations.

The cooperation between the Reconstruction Administration and the experiment station has been cordial and effective throughout the year.

COOPERATION WITH THE CIVILIAN CONSERVATION CORPS

Thirty workers were made available by the C. C. C. throughout the year.

Thirty workers were made available by the Civilian Conservation Corps at the beginning of the year and later increased to 55 men. The men were employed primarily for the propagation of the newly introduced species of industrial bamboos, but with the approval of the Administrator this personnel was used also to accelerate the propagation of the tropical tung-oil species (*Aleurites trisperma*) and some of the species, such as *Acacia farnesiana* and *Haematoxylon campechianum* which can be used as hillside covers in arid or semiarid

regions. Considerable acreages of permanent plantings of the industrial bamboos (*Bambusa tulda*, *B. tuldoides*, and *Dendrocalamus strictus*) were made with the C. C. C. personnel.

A permanent planting of *Aleurites trisperma* was started on previously waste hillside land during the year. Both nurseries and permanent plantings of quinine at Las Mesas and at Maricao were maintained by men from the C. C. C. brigade.

C. C. C. men constructed 1.6 kilometers of plantation road during dry season.

In the dry season, when neither propagation nor permanent plantings could be done effectively, the C. C. C. men constructed a gravel road into the old mango orchard, 80 meters in length. Three-hundred and seventy-five meters of gravel road were constructed into the Jagua Valley, leading eastward along the north side of the valley floor. Work was then started on a switch-back road starting from the Miradero Road and proceeding northeastward through the main pasture, to reach the southern rim of the Jagua Valley and continue eastward inside of the valley rim. At the beginning of the rainy season when the work had to be discontinued because of the pressure of planting and weeding work with bamboo, this road had reached the easternmost border of the lowland property and had curved northward and then westward, descending to reach the floor of the Jagua Valley. This road, with no sustained grade of more than 10 percent, had been partly surfaced with gravel and was passable for automobiles as well as farm wagons during dry weather. All cuts and fills were made at angles considerably less than the angle of repose and were immediately fertilized and planted to grass to prevent erosion. The plantation road constructed by the C. C. C. brigade during the dry season totaled 1.6 kilometers.

COOPERATION WITH OTHER AGENCIES OF THE FEDERAL GOVERNMENT

Soil Conservation Service has built plantation roads.

Two large laboratories at the station were made available for the use of the Soil Conservation Service of the United States Department of Agriculture during the year. Approximately 38 acres of land at the station were also made available for tests of various soil-erosion-prevention methods and for run-off studies.

The Soil Conservation Service constructed approximately 896 meters of plantation road with gravel surfaces, adequate culverts, and drainage. A combination dam and bridge of a design new to Puerto Rico was also constructed to show a method of checking floodwaters. Such improvements by the Service have added greatly to the physical value of the property of the experiment station.

Bureau of Chemistry and Soils cooperated in essential-oil and drug projects.

The Bureau of Chemistry and Soils has helped to guide the projects on essential oils, spices, and drug crops. The services of E. K. Nelson, senior chemist of the Division of Food Research, have already been mentioned; in addition, the personnel of this Bureau contributed to research progress at the station through correspondence and conferences.

Bureau of Animal Industry has aided in supervision of station dairy herd.

The experiment station has a fine herd of registered Guernsey dairy animals. The personnel of the Bureau of Animal Industry stationed in Puerto Rico has shown interest in this herd and has contributed considerably of its time and professional services in the maintenance of the herd in such an excellent condition. The experiment station has cooperated in making its resources available for the activities of the Bureau.

Bureau of Entomology and Plant Quarantine has cooperated in tropical fruit studies.

Laboratory facilities and other services have been made available to the Bureau of Entomology and Plant Quarantine for its personnel engaged in studies of cotton insects and the West Indian fruitflies. The work has yielded definite results that have material economic importance to the fruit industries of Puerto Rico. Laboratory and office space has also been provided for the personnel of the plant-quarantine service of the same Bureau. The personnel of the Bureau has cooperated from time to time in contributing professional advice in the entomological and horticultural studies of the experiment station.

Forest Service has made land and technical personnel available.

The Forest Service has made available land in the Caribbean National Forest at Maricao for quinine plantings and nurseries. The personnel of the Forest Service, with a different professional background, have also contributed suggestions for the work of the station. The experiment station makes available 20 acres of land as a nursery for the Forest Service. The mutual interchange of facilities has been most advantageous for the Government.

Geological Survey of the Interior Department is housed at the experiment station.

In May 1938 the experiment station was requested by the Department of the Interior to place office facilities at the disposal of the personnel of the Geological Survey. Desirable office and storage space was made available during the year. The Geological Survey has maintained five or six men of their technical personnel centered at Mayaguez. The relationship with this personnel has been advantageous for the experiment station and the work of the Government.

IMPROVEMENTS IN PROPERTY

Road construction has made all parts of station accessible.

Because of the aid given by the Puerto Rico Reconstruction Administration and the Civilian Conservation Corps, noteworthy improvements have been made in the physical property of the experiment station. Much of the 400 acres of land of the station in the past has been inaccessible except on foot or horseback and, therefore, considerable of the area was seldom visited and little used. As a result of the cooperation furnished by the Reconstruction Administration, the Civilian Conservation Corps, and the Soil Conservation Service, there is now little of the station property which is not readily accessible for farm wagons and, in most cases, for motor vehicles. In this

development work, experience has been gained also as to the most economical and effective types of plantation road construction under the peculiar conditions of steep hillsides and heavy rainfall which exist in most of the coffee districts of the island.

Station lands are now protected against erosion.

The supply of irrigation water has been increased and, at the same time, flood control has been improved. A considerable part of the station property is now protected against losses from soil erosion by contour canals. The fencing of the property has been extended and improved. The Department of the Interior of the Insular Government with the cooperation of the Bureau of Public Roads of the Department of Agriculture rebuilt the Miradero Road which passes through the center of the station property. The road has a Telford base and asphalted surface. The construction of this road has permitted improvements in the landscaping of the property and added another beautiful entrance to the station grounds.

The reservoir at Las Mesas furnishing the water supply to the station buildings in the lowland was improved to minimize flood damage and prevent the entrance of surface water.

PUBLICATIONS

Many requests are made for mimeographed monthly reports.

The issuance of an interoffice report each month in mimeographed form was continued. These reports contained the most important results of the work of the station as it progressed during the year. There were increasing requests for copies of this monthly interoffice statement; each issue was sent to a mailing list of about 80 persons, interested local planters and experiment station workers, as well as personnel of the Department of Agriculture. There were three supplements to the January report and one to the June report; 316 pages in all, including an index to the subject matter of 101 individual reports.

Six numbers were added to the Agricultural Notes series.

Six articles by Department workers in Puerto Rico were published in the Agricultural Notes series of the station. These articles were mimeographed in both English and Spanish in editions of approximately 1,000 copies each.

The titles and authors of the six numbers issued during the year and the number of pages in each are listed below:

No. 80. The Introduction and Colonization in Puerto Rico of *Macrocentrus ancylivorus*, by Kenneth A. Bartlett, assistant entomologist, Division of Foreign Parasite Introduction, Bureau of Entomology and Plant Quarantine. 4 pages.

No. 81. The Pink Bollworm of Cotton in Puerto Rico during 1936 and Recommendations for its Control, by L. Courtney Fife, Bureau of Entomology and Plant Quarantine. 9 pages.

No. 82. A Preliminary Report on the Control of Leaf Chlorosis of Grapefruit in Puerto Rico, by James H. Jensen, plant pathologist and physiologist. 5 pages.

No. 83. Studies of Sugarcane Insects Conducted by the United States Department of Agriculture in Puerto Rico, by H. D. Tate and F. M. Wadley, Bureau of Entomology and Plant Quarantine. 3 pages.

No. 84. The Introduction and Colonization in Puerto Rico of Predatory Beetles Which Attack Coconut Scales, by Kenneth A. Bartlett, assistant entomologist, Division of Foreign Parasite Introduction, Bureau of Entomology and Plant Quarantine. 9 pages.

No. 85. The Introduction into Puerto Rico of a Parasite of the White Scale of Papaya, by Kenneth A. Bartlett, assistant entomologist, Division of Foreign Parasite Introduction, Bureau of Entomology and Plant Quarantine. 2 pages.

Annual Report was translated into Spanish.

After having been issued in English during the early part of the fiscal year, the annual report for 1936, which contained 103 pages and 18 illustrations, was translated into Spanish for circulation among island farmers and in Central America and South America.

CHANGES IN PERSONNEL

The station lost personnel with valuable accumulated tropical experience.

During the year Alfred N. Watson, biometrician and plant physiologist, resigned effective September 1, 1937, to accept a fellowship permitting the study of biometrical methods at the Galton Laboratory of University College, London, England. José Brunet, minor scientific helper, resigned November 23, 1937, to accept a position with the Insular Government. H. L. Van Volkenberg, parasitologist, resigned December 15, 1937, to become professor of parasitology and head of that department at the Agricultural and Mechanical College of Texas. James H. Jensen, plant pathologist and physiologist, resigned effective January 8, 1938, to accept a position as associate plant pathologist at the University of Nebraska.

Workers with agricultural experience in the Tropics are somewhat limited in the continental United States. The resignations of the foregoing personnel result in a loss of accumulated experience in tropical agriculture to the experiment station which it is difficult to replace.

J. K. Alvis was appointed as assistant agricultural engineer, effective August 13, 1937, and A. G. Kevorkian as scientific aide in plant pathology and physiology, effective August 12, 1937.

Shortly after the beginning of the fiscal year a number of appointments were made under the appropriation from the Legislature of Puerto Rico. Francisca E. Arana was appointed assistant chemist in vanilla investigations, effective August 1, 1937, and also received Federal appointment as collaborator effective September 18, 1937. Mrs. Noemí G. Arrillaga was appointed assistant chemist in the investigations of essential oils, effective August 1, 1937, and as collaborator effective May 19, 1938. William Pennock was appointed assistant agronomist in spice and drug crops, effective August 1, 1937, and as collaborator effective October 16, 1937. Carlos Raúl Saavedra was appointed assistant agronomist in studies of essential-oil crops, effective September 1, 1937, and as collaborator effective April 5, 1938. Astor González was appointed librarian under the Insular appropriation effective August 1, 1937. Reports of the activities of these new members of the staff already have been presented on the foregoing pages.

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